

Interdisciplinary Excellence Accelerator Series

Christian Brecher · Günther Schuh  
Wil van der Aalst · Matthias Jarke  
Frank T. Piller · Melanie Padberg *Editors*

# Internet of Production

Fundamentals,  
Methods and Applications

INTERNET OF  
PRODUCTION | RWTH AACHEN  
UNIVERSITY

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# **Interdisciplinary Excellence Accelerator Series**

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Aachen, Germany

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The Interdisciplinary Excellence Accelerator Series (IDEAS) is an innovative book series highlighting interdisciplinary and excellent research conducted at universities, such as the 'Cluster of Excellence' at RWTH Aachen University, Germany, and their collaborating partners across the world. The series enables a new form of fast publication anchored in the spirit of interdisciplinary collaboration from authorship to review to dissemination.

These high-quality books can be used by scientists, practitioners, and students for different purposes ranging from teaching to research and knowledge transfer. The series contains both English and German-language books, and focuses on fields such as, but not limited to:

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- Business and Societal Dimensions of Technology
- Mobility and Transport Engineering
- Material Science and Engineering
- Medical Science and Technology
- Computational Science and Engineering
- Energy, Chemical and Process Engineering
- Molecular Science and Engineering

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Editors

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Fundamentals, Methods and  
Applications

With 160 Figures and 4 Tables

 Springer

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# Preface

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## **Crossing Disciplinary Boundaries: RWTH Aachen and Springer Start a New Publishing Partnership**

This first volume of the new Interdisciplinary Excellence Accelerator Series (IDEAS) is the first major outcome of more than a year of joint work with its inception in a 2-day publishing lab workshop with researchers from the Excellence Cluster “Internet of Production” at RWTH Aachen (Germany) and editors from Springer held in March 2021. The aim of the online event was to understand current researcher needs and pain points, as well as exploring ideas for potential solutions.

The event was well prepared – including a survey which RWTH Aachen addressed to students and researchers at their Cluster of Excellence – and eventually centered around two main themes in research and publishing:

- How to accelerate the journey from research to publication and scholarly knowledge transfer?
- How to facilitate truly interdisciplinary research and publishing?

In what follows, we put forward the three tenets which the participants of this workshop have agreed upon as the way to encourage, enhance, and propagate accelerated interdisciplinary work.

### **Tenet 1: Reduce the Time Between Research, Publication, and Scholarly Knowledge Transfer**

Scientific research has accelerated dramatically over the last decades. This is not only a consequence of the rise of digital technologies and the Internet. Emergencies such as the Covid pandemic and the climate crisis have also increased the political and public demand for faster research outcomes. The development of effective Covid-19 vaccines in less than one year after the pandemic hit can be considered as an impact of such demand.

On the academic side, researchers with good reason would say: *If you want us to produce research results faster, then you have to provide us with the appropriate tools, resources, and dissemination infrastructure.*

Academic publishers have not always fully understood current researchers' needs in their actual lab and scholarly environments. Particularly, it takes too much time for research results to become available in the scholarly knowledge transfer and teaching. One can highlight this by pointing to textbooks which, in many cases, take between 3 and 5 years from conception to their release. By that time, the presented research results and data are often outdated already. This might have been fine in former decades with a much slower pace of the research progress. In a time of accelerated research, this is not fast enough anymore which is a severe problem.

At the publishing lab, we clearly addressed that research publishers need to find solutions to bring current research outcomes into the scholarly knowledge transfer and academic teaching with a much faster turnaround. And there are a number of ways to do so:

- An “Online First” publication may be one part of the mix.
- Solutions to provide researchers, teachers, and students with the ability to compile and recompile their material themselves according to current status and requirements may be another part.
- Keeping content up to date in a more continuous way instead of publishing new editions every 3 to 5 years is yet another component.

Many of such partial solutions already exist, yet the challenge is to combine them in a smart and convenient way – also balancing the classical triangle of time, quality, and value – so they have a positive impact on scholars.

## **Tenet 2: Make Interdisciplinary Review Mandatory**

The second major theme of the publishing lab was the interdisciplinary aspect of research. It is a matter of fact that the global challenges of our days require researchers to overcome the boundaries of the discipline silos. In consequence, the Cluster of Excellence “Internet of Production” at RWTH Aachen puts a particular focus on interdisciplinary research: “With the Internet of Production, our vision is to enable a new level of cross-domain collaboration” (<https://www.nature.com/articles/d42473-019-00089-5>).

Yet, the reality in research and publishing does not always fit with such demand for interdisciplinary research as we discussed at the publishing lab:

- Although it is often quite clear which academic disciplines are required to collaborate on a given field of problems, it is a common experience that putting researchers from different disciplines at one table is not sufficient as they might not understand each other due to the languages, jargons, and even the academic approach specific to their disciplines.

- While interdisciplinary research is the order of the day, research communities tend to prioritize and reward the outcomes and publications within their own disciplines rather than interdisciplinary work.
- Research methods and data frequently stay within their discipline boundaries instead of being mutually shared between the disciplines, where applicable.
- Existing publishing formats do not intrinsically encourage researchers to cross the bridge to other disciplines.

The discipline silos also become apparent when it comes to peer-review. Peer-reviewers, by the nature of their remit, may not bridge the gap between the disciplines and at the same time, cross-discipline<sup>1</sup> reviewer recommendation is not a common feature in peer-reviewer finder tools either.

In the ideal world of the Excellence Cluster “Internet of Production,” the reality would look as in this simplified example:

1. A researcher in Mechanical Engineering shares research data from the lab.
2. A Computer Scientist reviews the data and writes an analysis.
3. A Social Scientist reviews the analysis and writes a reflection.
4. Every single step is published and adds to researchers’ credits.
5. All three pieces together (points 1, 2, and 3) make up for the final research publication.

We also thought about where exactly do people from different domain backgrounds come together and actually talk to each other as well as jointly experiment on their ideas. In the IT and tech domain, this is common practice and is termed “hackathons.” So why not establish dedicated peer-review events that follow a cross-domain approach such as hackathons do. Such events would also accelerate the reviewing itself. And more than that, events like this might over time help cultivate a language that different disciplines understand and which would also help building interdisciplinary communities and allow cross-discipline application of methods hitherto used in siloed disciplines only.

### **Tenet 3: Use books as calls to action and solution vehicles**

This first book of the Interdisciplinary Excellence Accelerator Series (IDEAS) is a starting point. It is composed of chapters each of which has been prepared by an interdisciplinary research team. In the spirit of agile development, we want to iterate over the course of the next 2 to 3 years in order to introduce a new way of collaboration (including dedicated review events) together with a new research

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<sup>1</sup> In this introduction, the terms “cross-discipline” and “interdisciplinary” are being used interchangeably.



publishing format which we call *Crosstracts*. It is this new concept of *Crosstracts* which will allow researchers to:

- Find potential collaborators at an early research stage
- Publish research and research data early and faster
- Recognize the various stages of the knowledge and manuscript creation
- Make interdisciplinary review and feedback mandatory, collaborative, and transparent in a novel and constructive manner
- Facilitate interdisciplinary research with a positive impact on global challenges and societal recognition
- Boost the creation of cross-discipline communities with a language and knowledge configuration that all participants understand
- Resulting in a cross-discipline book series that is engineered in such a way that it crosses the boundaries of single disciplines with a much earlier re-usability in the scholarly knowledge transfer (in German: “*akademische Lehre*”)

There is a reason why we decided to begin with a book series. First of all, books are a great opportunity to experiment, iterate, and adjust on the way forward. But there is more to it. Books have an impact both on the consumption side – i.e., for their readers – as well as on the side of their creators. The various existing book categories – such as monographs, handbooks, textbooks, encyclopedias – all require their authors to create them in a specific way. In consequence, books are not only helping their readers to achieve certain goals, e.g., passing exams. Books are increasingly also specific calls to action toward their authors themselves.

This is exactly what a *Crosstracts* book series wants to achieve: Make it obligatory to interdisciplinary research teams to not only collaborate but also mutually review each other’s research and hence truly understand and influence each other, so *the whole of their interdisciplinary research becomes greater than the sum of their discipline-specific parts*. In that very sense, books are not only representing research outcomes to an audience. They are also an excellent solution vehicle for research teams in general.

It is a beginning of the change which academia has always been seeking, and it is an ongoing process. We call upon readers of this publication to come forward and suggest further improvements, ideas, or initiatives to contribute to a new reality of truly interdisciplinary, fast, and impactful scholarly knowledge transfer.

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## Editorial

With the Cluster of Excellence Internet of Production (IoP), more than 200 scientists from the fields of production engineering, computer science, materials engineering, social science, and business administration are simultaneously facing up to the task, but also the obligation, of addressing future challenges and goals for production technologies with all their facets to generate innovative solutions and practical concepts to shape the production of tomorrow.

The vision of the IoP is to identify relevant data from production, development and use in real time, select, and reduce it in a form that it can be used adequately by solving interdisciplinary tasks and thereby provide the decisive research impetus for shaping the future of digitalization in production engineering. This involves industrial artificial intelligence, advanced manufacturing and materials, intelligent data infrastructures, and a holistic view of the future of work. This means the main task is to derive and create real added value from the gigantic amounts of data that already exist in all areas of production – for the entire production itself, the individual machine, and all the people involved – described by transferring the IoT to the world of production.

Interdisciplinary publishing presents us with major challenges. What is already “state of the art” for some is applied in another discipline new research for others. By linking topics that have already been researched in different disciplines, new fields of research emerge as limitations are re-challenged. Each discipline has its own language, styles, and requirements for scientific publishing. Whereas in one discipline the description of applications and use cases is mandatory, in others they are considered to be delicate or even frowned upon. And even the internal review process, with different disciplines looking at each other, cannot always be fully transferred to the topics. Often, no direct feedback on the work can be given, but rather a new perspective can be shown, an outlook on upcoming topics can be considered, and a dialog is created that requires and enables a view beyond one’s own focus.

Fortunately, together with Springer, we were given a unique opportunity to understand and approach publishing in a new way. We developed a new series called Interdisciplinary Excellence Accelerator Series (IDEAS). The series enables a new form of fast publication anchored in the spirit of interdisciplinary collaboration from authorship to review to publication. The resulting high-quality books can be used

both by academics and practitioners for different purposes ranging from teaching to research and knowledge transfer. This book is the first of this series.

To provide a fast publication process and taking in account that most readers only read certain chapters of their interest, the individual chapters of the book are intended to stand on their own. The book is intended to provide an overview of the challenges of tomorrow's production technology and describe initial approaches to solutions along the way.

This book presents and summarizes the interim results of the Cluster of Excellence during the first half of the funding phase under the Excellence Strategy. For more detailed results, reference is made to corresponding scientific publications. An update with further research results will follow.

We would like to thank all scientists for their extraordinary commitment and excellent results, as well as the German Research Foundation (DFG) for funding the Cluster of Excellence "Internet of Production" in the funding period of the Excellence Strategy.

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Aachen  
May 2023

Prof. Christian Brecher  
Prof. Günther Schuh  
Prof. Dr. Wil van der Aalst  
Prof. Matthias Jarke  
Prof. Frank T. Piller  
Melanie Padberg

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## About the Editors

**Prof. Dr.-Ing. Christian Brecher** has held the Chair of Machine Tools at RWTH Aachen University since January 2004. His research areas include machine technology, machine data analysis and NC technology, control technology and automation, gear technology, precision machines, fiber composite technology, and integrative lightweight construction. At the same time, he became a member of the Board of Directors of the Laboratory for Machine Tool and Production Engineering (WZL) and of the Fraunhofer Institute for Production Technology IPT in Aachen.

From 2006 to 2018, Prof. Brecher was spokesperson for the Cluster of Excellence “Integrative Production Technology for High-Wage Countries” at RWTH Aachen University. In 2012, he founded the Aachen Centre for Integrative Lightweight Production (AZL) together with Prof. Hopmann. In 2018, Prof. Brecher was appointed Director of the Fraunhofer Institute for Production Technology IPT. Currently, Prof. Brecher is also, among other positions, spokesperson for the Cluster of Excellence EXC2023 “Internet of Production” (IoP) at RWTH Aachen University, spokesperson for the SFB/Transregio 96, Fellow of the International Academy of Production Engineering (CIRP), and member of the German Academy of Science and Engineering (acatech). In 2020 and 2021, he was President of the Scientific Society for Production Engineering (WGP).

**Prof. Dr.-Ing. Dipl.-Wirt. Ing. Günther Schuh** has held the Chair of Production Engineering at RWTH Aachen University and is a member of the Board of Directors of the Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University and the Fraunhofer-Institute for Production Technology (IPT) in Aachen. He is also Director of the Research Institute for Industrial Management at RWTH Aachen University (FIR e. V.). Additionally, he is one of the deputy spokesperson of the Cluster of Excellence “Internet of Production” at RWTH Aachen University. In 2005, Prof. Schuh initiated the RWTH Aachen Campus, a network of science and business with currently more than 420 technology companies.

As a scientist and entrepreneur, Prof. Schuh is concerned with disruptive innovations, information and production management, as well as sustainable mobility

solutions. He supports the approach that complex interrelationships and systemic innovations require scientific and entrepreneurial collaboration. For more than 30 years, he has been working on issues of innovation and technology management, industrial production, and complexity management in industrial systems. With researchers and developers in the industry, he has repeatedly proven to develop cost-effective industrially manufactured products, especially electric vehicles, with Industry 4.0-based highly iterative development processes as well as new product and production architectures. In order to implement new mobility concepts into practice, he is still the founder of various companies that develop and produce mobility solutions. The focus is on holistic solutions to drive the transformation to new individual transport.

**Prof. Dr. Ir. Wil van der Aalst** is Full Professor at RWTH Aachen University, leading the Process and Data Science (PADS) group and deputy spokesperson of the Cluster of Excellence “Internet of Production” at RWTH Aachen University. He is also the Chief Scientist at Celonis, part-time affiliated with the Fraunhofer FIT, and a member of the Board of Governors of Tilburg University. His research interests include process mining, Petri nets, business process management, workflow management, process modeling, and process analysis. Wil van der Aalst has published over 900 articles and books and is considered to be in the top-15 of most cited computer scientists with an H-index of 170 and more than 130,000 citations.

Van der Aalst is an IFIP Fellow, IEEE Fellow, ACM Fellow, and received honorary degrees from the Moscow Higher School of Economics (Prof. h.c.), Tsinghua University, and Hasselt University (Dr. h.c.). He is also an elected member of the Royal Netherlands Academy of Arts and Sciences, the Royal Holland Society of Sciences and Humanities, the Academy of Europe, and the North Rhine-Westphalian Academy of Sciences, Humanities and the Arts. In 2018, he was awarded an Alexander-von-Humboldt Professorship.

**Prof. em. Dr. Matthias Jarke** is Professor em. of Databases and Information Systems at RWTH Aachen University. After his Doctorate from Hamburg University in 1980, he held professorships at the Stern School of Business at New York University and the University of Passau before joining RWTH in 1991. Key teaching contributions focus on RWTH internationalization, founding the Bonn-Aachen International Center for IT (b-it) and as Inaugural Dean at the GUTech German University of Technology in Oman. After 8 years as Chairman of Aachen’s CS Department, he became Executive Director of the Fraunhofer Institute for Applied Information Technology FIT. As ICT representative in the Fraunhofer Presidency 2010–2015, he co-initiated the International Data Space concept for European data sovereignty.

Jarke’s research addresses database query processing, metadata management, requirements, and information systems engineering. Large interdisciplinary projects studied Chemical Engineering processes, Media and Cultural Communication, and Highspeed Mobile Information and Communication. Currently, he serves as deputy spokesperson of the Cluster of Excellence “Internet of Production” at RWTH

Aachen University. As President of the GI German Informatics society, Jarke coordinated the BMBF Science Year 2006, which started the German Chancellor's Digitalization Summits. He was elected to the German Academy of Technology and Sciences acatech and received prestigious awards including ACM Fellow and GI Fellow.

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