Cyber Physical Systems (Part 2)

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As pointed out in a recent position paper by acatech, the German Academy of Technical Sciences, in line with Moore's Law, ongoing advances in very large scale digital circuits integration enable electronic components ever smaller, more powerful, and cheaper. As a result, devices and objects are increasingly equipped with embedded systems connected directly to the physical world through a range of sensors and actuators, and that, consequently, can be deployed in a broad range of applications in ways allowing them to be controlled, monitored and networked. Global networks such as the Internet connect embedded computers, their data, their services and their applications. Embedded systems, electronics, and software are significant drivers of innovation and growth for export markets of industrial countries – expanding significantly functionality and thus the utility value and the competitiveness of vehicles, aircraft, medical equipment, production equipment and household appliances. Already, about 98 percent of the microprocessors work embedded, connected by sensors and actuators to the physical world. Increasingly, they are linked among themselves and to the Internet. The physical world merges with the virtual world of cyberspace leading to Cyber-Physical Systems (CPS) and to an Internet of things, data and services.

Cyber-Physical Systems are a significant element of a future globally connected world in which products, equipment, and objects with embedded hardware and software applications interact. Using sensors these systems collect data from the physical world and make them globally available for services in networks. By their actuators software systems can interact directly with events in the physical world.

Initial instances of cyber-physical system exist already today – for instance in the form of networked software navigation. To improve the turn-by-turn navigation mobile data and congestion information from present motion profiles from traffic is used. Other examples are assistance and traffic control systems from the fields of avionics or rail traffic. Here we find actively controlling systems access. Future Cyber-Physical Systems contribute to safety, efficiency, comfort, and people's health.

As part of a Smart Grid, Cyber-Physical Systems control the future power supply systems consisting of a large number of renewable energy producers. Cyber-Physical Systems will in future control the energy traffic through coordination and contribute to reducing CO_2 emissions. Modern Smart Health systems network patients and doctors and allow remote diagnosis and medical care at home. Internet-based systems offer remote control for autonomously working production systems created for industrial production, logistics and transportation. A next step is to self-organization. Machines regulate their maintenance and maintenance strategy for each load level autonomously and provide for maintenance-related interruption to save capacity to maintain production.

Cyber-Physical System pose new challenges in science and research: how to deal with heterogeneous networked structures, how to produce a holistic and systemic view of interdisciplinary collaboration of mechanical engineering, electrical engineering and computer science. Cyber-Physical Systems require technology to control how they are to be built, managed, controlled, and maintained.

Via Cyber-Physical Systems devices and objects are linked together through software-intensive systems and networks. Countless devices provide access to this virtual environment through their human-machine interfaces. New solutions and cyber-physical services are formed "in the cloud". The results are cyber-physical systems that offer revolutionary applications and benefits. The innovations that can be attained and realized in such systems, and their impact, extend well beyond anything we can currently imagine.

The solutions that are produced by the high speed of innovation are never good enough or sufficiently comprehensive in their first iteration, due to their complexity and degree of innovation, and as a result demand evolutionary improvements. These open up new opportunities and consequently lead to yet more innovative solutions. Innovation enters a rapid spiral process. Associated with this development are not only rapidly changing habits and demands on users, but also new, disruptive business models and growing eco-systems within the economy.

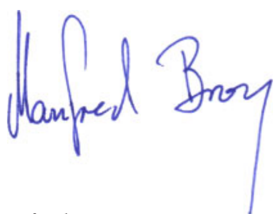
The full extent of the innovations can only be totally exploited by implementing targeted measures.

Software-intensive systems and devices have become everyday consumables. Thanks to their multifaceted support for networking and inclusion of data and services from global networks, they are evolving to form integrated, overarching solutions that are increasingly penetrating all areas of life. The results are open, networked Cyber-Physical Systems that create system environments and socio-technological systems with revolutionary applications.

The contributions of this second part of the special issue on Cyber-Physical Systems again address some of the most relevant fields of CPS. Multi-core architectures are likely to become the basis for embedded systems of the future as they will be appearing in Cyber-Physical Systems. In their article, Claudia Eckert and Thomas Kittel point out new security risks that come with the particular characteristics of multi-core architectures and discuss necessary lines of future research to equip multi-core systems with appropriate security concepts. The need to systematically design and implement extensive Cyber-Physical Systems calls for new architectural patterns. The contribution by Ingolf Krüger focuses on architectural integration aspects and presents an approach based on service-oriented architectures to address their dynamic change during the execution of a CPS. Trustworthiness is an indispensable prerequisite for achieving acceptance of the new cyber-physical technology by users. Oliver Sander, Alexander Klimm, and Jürgen Becker argue that cryptographic solutions have to be embedded in order to provide the necessary security and privacy measures. Focusing on the challenge of authentication, their contribution describes hardware-software architectures to integrate security building blocks within even the smallest parts of a CPS.

Altogether the contributions in this special issue on Cyber-Physical Systems impressively show the wide spectrum of the field and the many scientific and technical challenges in this area. It is a pleasure to see the potential of Cyber-Physical Systems and the many stimulating research questions related to it. We hope that this special issue can contribute to the development of the field.

It is a pleasure to thank the authors for their contributions and, as well, Holger Pfeifer and Georg Kalus for their help in putting together this special issue.



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Prof. Dr. Manfred Hans Bertold Broy studied Mathematics and Computer Science at the Technical University of Munich. He graduated in 1976 with the Diplom in Mathematics and Computer Science. In February 1980 Manfred Broy received his Ph.D. and in 1982 he completed his Habilitation Thesis: "A Theory for Nondeterminism, Parallelism, Communication and Concurrency". In April 1983 he became a full professor for computer science and the founding dean at the Faculty of Mathematics and Computer Science at the University of Passau. In October 1989 he became a full professor for computer science at the Faculty of Computer Science the Technische Universität München (former chair of Professor F. L. Bauer).

His research interests are software and systems engineering comprising both theoretical and practical aspects. This includes system models, specification and refinement of system components, specification techniques, development methods and verification. He is leading a research group working in a number of industrial projects that apply mathematically based techniques and combine practical approaches to software engineering with mathematical rigor. There the main topics are requirements engineering, ad hoc networks, software architectures, componentware, software development processes and graphical description techniques. In his group the CASE tool AutoFocus was developed.

Prof. Dr. Dr. h. c. Broy has received a number of awards for contributions to science: Gottfried Wilhelm Leibniz Award of the German Science Foundation (1994), Federal Cross of Merit (1996), Doctorate Honoris Causa, University of Passau (2003), Bavarian State Award for Education and Culture (2006) and Konrad Zuse Award for Computer Science (2007). He is a member of: Board of Trustees of Fraunhofer Institute, European Academy of Science, German Academy of Natural Scientists "Leopoldina", Association of Computer Sciences and acatech-Council for Technical Sciences. He has a Max-Planck Fellowship.

Throughout his academic career Prof. Dr. Dr. h. c. Broy has maintained strong contacts with industry, through consultancy, teaching and collaborative research projects and he has published more than 300 scientific publications. His main field is Software & Systems Engineering and his current research interests are: the System Development Processes and Tool Support, Concurrent and Embedded Systems, Theoretical Foundation of Informatics, IT Security and Requirements Engineering.

One of the mains theme of Manfred Broy is the role of software in a networked world. As a member of acatech under his leadership the study Cyber-Physical Systems was created for the Federal Ministry of Research to comprehensively investigate the next stage of global networking through the combination of cyberspace and embedded systems in all their implications and potential.

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