Abstract. Control theory is an interdisciplinary field that is located at the crossroads of pure and applied mathematics with systems engineering and the sciences. Recently the control field is facing new challenges motivated by application domains that involve networks of systems. Examples are interacting robots, networks of autonomous cars or the smart grid. In order to address the new challenges posed by these application disciplines, the special focus of this workshop has been on the currently very active field of Cyber-Physical Systems, which forms the underlying basis for many network control applications. A series of lectures in this workshop was devoted to give an overview on current theoretical developments in Cyber-Physical Systems, emphasizing in particular the mathematical aspects of the field. Special focus was on the dynamics and control of networks of systems, distributed optimization and formation control, fundamentals of nonlinear interconnected systems, as well as open problems in control.

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Introduction by the Organisers

Control theory is an interdisciplinary field that is located at the crossroads of pure and applied mathematics with systems engineering and the sciences. Traditionally, the interaction with systems engineering and signal processing has been particularly strong. More recently, deep interactions are emerging with new application areas, such as network sciences, robotics and information technology. The field therefore covers a wide variety of topics, ranging from fundamental mathematical
aspects and new control paradigms in the sciences to real world engineering applications of industrial relevance. In particular, it has deep connections to different branches of pure and applied mathematics, including e.g. ordinary and partial differential equations, operator theory, real and complex analysis, probability theory, numerical analysis, discrete mathematics and graph theory, as well as algebraic and differential geometry.

The Oberwolfach workshop “Control Theory: A Mathematical Perspective on Cyber-Physical Systems” brought together 56 internationally active researchers from Australia, Austria, Canada, China, Germany, Israel, Italy, Japan, The Netherlands, Russia, Sweden, Switzerland, United Kingdom, and the United States, with both a mathematical and systems engineering background. Cyber-Physical Systems (CPS) is a new field which offers an enormous potential for applications of pure and applied mathematics. Thus special focus of this workshop has been on the interaction between mathematical systems and control theory and cyber-physical systems. This was enhanced by nine survey lectures on recent developments in CPS and complemented by an open discussion session on mathematical aspects of cyber-physical systems. Topics of these lectures included the foundational aspects of cyber-physical systems, algorithmic aspects of cyber-physical networks, control of rigid formations, chemical reaction networks, distributed optimization, hybrid control synthesis for multi-agent systems, distributed randomized algorithms in social and sensor networks, and data-driven cyber-physical model estimation. To complement these survey talks by challenging mathematical and systems engineering topics, a series of lectures was devoted to the control of interconnected systems, another current research topic that is of very strong interest to the systems engineering community. In all these talks, the interaction of mathematical methods from nonlinear dynamics and control with those from discrete mathematics (esp. graph and information theory) played a crucial role. Although several fundamental mathematical questions in cyber-physical systems are still unanswered or even unasked, it became evident through the workshop that the appropriate combination of mathematical tools will be instrumental for further success in this area.

The program comprised more than 20 stimulating talks on the theory and applications of control theory. The survey talks had a length of 45 minutes with 15 minutes discussion time, while the other special topics lectures were thirty-five minutes long, with at least 5 minutes discussion time. In addition to these lectures and the very active discussions throughout the workshop there was an open discussion session on mathematical aspects of cyber-physical systems and a Tuesday evening open problem session, in which participants presented six open mathematical problems in control. On Wednesday evening a small informal meeting took place on four challenging research topics, with focus on broad mathematical issues in systems and control theory. On Thursday evening there was poster session with about ten contributions. This session was very well attended and was a great success. Snow prevented the traditional Wednesday afternoon walk to St. Roman. Thus the excursion went to Wolfach, where we visited the excellent Museum on Mathematics and Mineralogy and enjoyed the famous black forest cake in a
nearby Cafe. As an additional social event, Brian Anderson and Matthias Müller delighted the workshop participants by a performance of works by Georg Philipp Telemann and Franz Schubert for violin and piano.

Altogether the workshop must be seen as a great success, in that many new ideas and solution approaches have been stimulated for the field of control of cyber-physical systems. A special feature of this workshop was the close interaction between mathematicians and engineers that has been very fruitful. Oberwolfach workshops in the area of control theory have the reputation of being the most prestigious and worthwhile to attend meetings in this field. This is the reason why this workshop attracted the leading researchers in the field, that have been brought together with young promising junior scientists. Many of the participants, including the senior people, commented that this has been the most interesting and rewarding scientific event they ever(!) attended. Quite a remarkable statement from researchers who have witnessed hundredth of conferences and workshops in their life.

The organizers would like to thank the Mathematical Research Institute, and especially its great staff, for the opportunity to spend a most fruitful week of scientific interaction there, and for the marvelous atmosphere that is being provided. This institute is a jewel whose positive influence on mathematics and beyond cannot be emphasized enough.

Acknowledgement: The MFO and the workshop organizers would like to thank the National Science Foundation for supporting the participation of junior researchers in the workshop by the grant DMS-1049268, “US Junior Oberwolfach Fellows”. Moreover, the MFO and the workshop organizers would like to thank the Simons Foundation for supporting Brian D.O. Anderson in the “Simons Visiting Professors” program at the MFO.
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