Empowering Automation and Control with Emerging ICT Technologies

Motivation and Background

New topics in information and communication technologies (ICT) such as the internet of things (IoT), big data, and 5G networks are receiving considerable attention today. Much of the interest is for non-real-time and non-closed-loop applications, but new ICT developments have considerable relevance for control systems—indeed, they could revolutionize the automation of physical systems. Highly distributed control architectures; pervasive sensing and connectivity; "cloud"-hosted monitoring, control, and optimization algorithms; large-scale analytics and system identification; autonomous and semi-autonomous operations . . . these and other visions will take tangible steps toward realization with substantive collaborations between the controls and ICT communities.

The "Trans-Atlantic Symposium on Technology and Policy for a Smart Society" (Minneapolis, MN, U.S.A.) provided an excellent opportunity to emphasize the relevance of control to ICT. The Symposium was held on June 19-20, 2017 at the McNamara Alumni Center at the University of Minnesota. It was organized under the auspices of the "PICASSO" support-action project funded by the European Commission's Horizon 2020 program. PICASSO is targeting EU/US collaboration in ICT policy, research, and innovation, with applications across the spectrum of "smart society" domains. The Symposium attracted 90 participants, over 40% of whom were from the Europe.

The ICT areas being targeted in the PICASSO project are cyberphysical systems and the internet of things (CPS/IoT), big data, and 5G communication networks—project subteams include expert groups on these technologies and also on ICT policy aspects. We are grateful for funding provided by the CSS Outreach Fund, which allowed us to invite a few guest speakers and students to ensure control science and engineering were well-represented at this event.

In addition to the European Commission, the University of Minnesota, and the IEEE Control Systems Society, other sponsors and partners for the symposium were the US National Science Foundation, Intelligent Manufacturing Systems, and Clean Energy Economy Minnesota.

Sessions and Discussions Related to Control Systems

Control was especially prominent in the IoT/CPS sessions, which focused on closing the loop with the Internet of Things for industry and infrastructure applications, and in several sessions devoted to smart society applications. Speakers that represented the control community included the following:

- Massoud Amin, Director, Technological Leadership Institute, University of Minnesota, USA (keynote speaker)
- John Baras, Professor, Department of Electrical and Computer Engineering, University of Maryland, US

- Sebastian Engell, Professor, Head of the Process Dynamics and Operations Group (DYN), Technical University Dortmund, Germany (conference cochair)
- Rolf Findeisen, Professor, Head of the Institute for Automation Engineering (IFAT), Otto-von-Guericke University, Germany
- Chris Greer, Senior Executive for Cyber-Physical Systems, National Institute of Standards and Technology, US (keynote speaker)
- Dinkar Mylaraswamy, Fellow, Honeywell Aerospace Advanced Technology, US
- Umit Ozguner, Professor Emeritus, Electrical & Computer Engineering, Ohio State University, USA
- Tariq Samad, Senior Fellow, Technological Leadership Institute, University of Minnesota (conference chair)
- Martin Serrano, Principal Investigator & Data Scientist, Insight Centre for Data Analytics, Ireland,
- Christian Sonntag, Senior Scientist, TU Dortmund, Germany
- Haydn Thompson, CEO, THHINK Group, United Kingdom, EU (keynote speaker)
- Hubertus Tummescheit, CEO & Co-founder, Modelon, Sweden

More details on the IoT/CPS sessions and on the "smart society" discussions during the symposium are given below.

IoT/CPS: Convergence of IoT and CPS for Smart and Dependable Socio-technical Systems

The three technical talks of the first IoT/CPS session, chaired by Prof. Sebastian Engell, focused on technology developments, challenges, and trends at the convergence of the internet of things and cyber-physical systems. This convergence is a major opportunity for future technical systems since the ubiquitous connectivity provided by IoT will "close the loop" in cyber-physical systems from a myriad of sensors to the way the systems are operated and also to the demands of the users. This will enable improved monitoring, management, and hence new levels of energy and resource efficiency, product and service quality, and safe and reliable operation for socio-technical systems such as electrical grids, railway systems, the public transport system of a city, and production processes.

After an introductory overview of the work of the PICASSO IoT/CPS Expert Group by Prof. Engell, John Baras gave a talk on networked cyber-physical systems and the Internet of Things in which he argued that most modern CPS are already networked, either via the internet or the cloud, or via special logical or physical networks. In these CPS, new fundamental challenges emerge on three fronts, at the interface between cyber and physical components (and their joint design), on the implications of the networked interfaces and the collaborative aspects of these systems, and on the incorporation of humans from the start. He then introduced new methods and technologies to deal with challenges in networked CPS, including new types of models based on coevolving multigraphs, distributed algorithms, dynamic coalition forming, and network virtualization.

Rolf Findeisen looked at the opportunities and challenges in IoT and CPS from a systems and control perspective. He argued that systems and control plays an important, enabling role and that the ubiquity

of communication, computation, sensing, actuating, and data leads to opportunities and challenges, such as resource utilization/attention, hierarchies and modularization to handle complexity, structured design and maintenance, and "personalization" of control and estimation.

Finally, Martin Serrano reviewed the state and promise for IoT in Europe. He gave an overview of the IoT landscape and the European IoT roadmap and provided a vision and challenges for future connected smart city systems and edge services, describing several major European initiatives in this area.

IoT/CPS: Research and Innovation Challenges and Opportunities for Transatlantic Collaboration

The second IoT/CPS session provided an overview of the major analyses and results in the area of IoT/CPS (published in the PICASSO IoT/CPS opportunity report) as well as industrial presentations and closed with a discussion on IoT/CPS technology challenges.

Session chair Tariq Samad gave an overview of the IoT/CPS Expert Group, followed by Christian Sonntag, who discussed the IoT/CPS opportunity report, describing drivers, needs, enabling technologies, EU and US research and innovation challenges and priorities, and technology themes that are important on both sides of the Atlantic.

Dinkar Mylaraswamy made a case for the intersection of IoT and CPS from the point of view of aircraft monitoring and maintenance, illustrating with several challenge problems why this domain will be a strong beneficiary of CPS, IoT, and big data analytics.

Hubertus Tummescheit argued for strong open standards as a necessary enabler for the collaborative design of cyber-physical systems. He noted that the landscape of computer-aided engineering (CAE) software is fragmented and that generic, compatible data standards are rare. He used the tool-independent, open Functional Mockup Interface (FMI) for model integration to illustrate how open standards can quickly boost innovation in different domains. He closed the statement with a call to action, stating that there is still plenty of room for standards that will simplify the design of CPS.

One conclusion from the two IoT/CPS sessions was that IoT in the EU is beyond the research phase and into the innovation phase. There will be a pruning of solutions; only some will survive. This makes IoT an enabling technology for CPS, with maturing solutions. However, this does not mean that the solutions will fulfill the security and safety requirements that many applications, especially closed-loop applications, need, and it is an important open issue how these requirements can be addressed.

Smart Cities, Smart Energy, Smart Manufacturing, Smart Transport , . . . but What Is "Smart"?
The "smart" theme was prominent throughout the symposium, and this led to reflections on what "smart" connotes in the context of the elements of a "smart society." The view was expressed that the word is losing its meaning, and we should work on a roadmap and taxonomy for defining smartness. In particular, we should be able to combine different dimensions, addressing the levels of core technology, of policy aspects, and of the application domains altogether.

Future urban scenarios were analyzed taking into account their complexity, elaborating on smart transportation scenarios, smart mobility trends, new urbanism, urban living labs and participatory

methodologies and open platform and technologies. It was stressed that urban environments are not just about efficiency and automation but that the needs and wants of citizens must also be fulfilled: The social context must be considered for technology deployment. The use of open data was highlighted as a way to share information among applications as well as to inform citizens and visitors.

Regarding the benefits of EU-US and academia-industry collaboration in smart cities, the panel highlighted how different smart city "verticals" have complementary strengths. Three strategies were offered by the panel to ensure that goals are negotiated effectively: 1) establishing trust between parties; 2) establishing clear goals, definitions and a plan of action; and, 3) providing visible leadership and a clear point of contact. The panel also advocated for the value of an agile, user-centered approach. In terms of EU-US collaboration opportunities in the energy sector, it was stressed how at this stage, it is important to widen the range of interlocutors beyond researchers, including (for example) accelerators.

Conclusion

The Symposium convened representatives of the academic, industrial and policy-maker communities from both the EU and the US in the areas of 5G networks, big data, the internet of things, and cyberphysical Systems, covering the spectrum of activities from strategic research prioritization, assessments of the state of the art, and precompetitive research needs, via commercialization opportunities, to policy issues impacting the ICT area. With support from Control Systems Society and its Outreach Fund, we were able to ensure that control technology was prominent in the discussions and presentations, and that selected students and experts working in control were exposed to the opportunities that new ICT developments offer our discipline.

The symposium agenda and most presentations are available at http://www.picasso-project.eu/projectevents/project-events/june-2017-symposium/. A summary of the symposium is available at http://www.picasso-project.eu/wp-content/uploads/2017/06/Project-Comm_MN-Symposium_June19_20-2017_vf.pdf and a detailed report is at http://www.picasso-project.eu/wp-content/uploads/2017/09/D4.6-Report-on-EU-US-conference_28-09.pdf. For more information on PICASSO, refer to http://www.picasso-project.eu/.

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