Introduction to the Special Issue on Self-aware Cyber-physical Systems

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CCS Concepts: • **Computer systems organization → Robotics**; **Sensor networks**; • **Computing methodologies → Dynamic programming for Markov decision processes**.

Additional Key Words and Phrases: Self-aware computing systems

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1 INTRODUCTION

A cyber-physical system (CPS) forms the borderline between the physical world in all its diversity and complexity, and the world of information processing which models the physical world, comprehends and predicts it for ultimately controlling it. CPSs, just like the physical world itself, are distributed, but where the data analysis, processing, computing and control should take place, remains a question that every application has to address for itself to find a reasonable solution that depends on physical distances, complexity of the task, requirements on response time, safety, security and privacy considerations. Computing efficiency, generality and flexibility of allocation of vast computing resources favor the realization of computing tasks in server farms, but various constraints on available communication bandwidth and energy supply as well as demands on latency, safety and privacy drive distributed processing and the provision of local intelligence.

The vision of self-aware computing is that a computing system has a comprehension of itself and its environment that is complete in the sense that it can relate to all relevant observations and make all required decisions. The field of self-aware computing systems has emerged in the early 2000s, with IBM's vision of autonomic computing formulated in 2003 as one main driver, and has become a diverse and rather mature area of research with various application domains and versatile techniques. It is often inspired by cognitive sciences and the remarkable capabilities of animals and humans. By firstly focusing on what is possible in principle the field has so far not prioritized questions of efficiency and what can be accomplished within tight constraints of energy and physical limits.

In contrast, cyber-physical systems consider resource constraints as first class citizens that shape and drive all design decisions. It has emerged at about the same time with its name being coined around 2006 by Helen Gill at the National

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Science Foundation. Although both research domains have already a rich literature and long history, only recently we have seen proposals to use concepts and techniques of self-aware computing in cyber-physical systems under tight constraints.

The following articles give an overview of this emerging area and exemplify some of the application cases. In *Self-Aware Cyber-Physical Systems* Bellman et al. give a comprehensive overview of all relevant topics, issues, challenges and some potential solution. Their article can serve as introduction to the field and summary of the state of the art.

Observing that CPSs often operate in groups and interact with other agents, some of them like and some of them very unlike themselves, Esterle and Brown in *I think therefore you are* discuss interaction patterns and models that CPSs build up about their partners based on the interactions observed. The authors postulate that, what they call *networked self-awareness* is a solid basis for extended autonomy of CPSs in environments consisting to a significant part of other CPS agents.

While learning must be an integral part of all self-aware systems and is a common theme in all articles of this special issue, it is the central focus of Sapio, Bhattacharyya and Wolf in the article *Runtime Adaptation in Wireless Sensor Nodes Using Structured Learning*. The authors contend that *Compact Markov Decision Process Models (CMM)* are a viable alternative to re-enforcement learning strategies for CPSs with tightly constrained resources when part of the actor's relation to the environment is well known at design time.

In *Efficient Holistic Control* Ma, Lu and Wang focus on control and discuss self-awareness across controllers in wireless networks. Aiming at increased autonomy and robustness against perturbations the authors explore self-awareness as a facilitator for improved control performance in wireless sensor-actuator networks.

The final article in this special issue is the most concrete one and focuses on a particular application. In *Self-aware Power Management for Maintaining Event Detection Probability of Supercapacitor-Powered Cyber-Physical Systems* Chai et al. apply concepts of self-awareness on the problem of power management in radar network systems under extreme power constraints. The article illustrates that a good and rather general understanding of the system's own condition, which is a hallmark of self-awareness, facilities robust behavior and good performance even under severe constraints of available resources.

This special issue provides a cross section of the research currently being conducted in this young and exciting field. We hope you obtain an overview of the concepts and approaches and find many novel insights and results, that inspire trigger new ideas. Most of all we hope you enjoy reading these articles.

Guest editors