

Preface

Cyber-physical systems (CPSs) are an emerging research topic born from the ever increasing complexity of engineered systems. Future systems will have to interact with each other and with the physical world in a very tight and well-coordinated fashion, and designing such systems is the research challenge behind CPSs. CPSs have been defined as “computational thinking and integration of computation around the physical dynamic systems where sensing, decision, actuation, computation, networking, and physical processes are mixed”. Given such a definition of CPSs, it is trivial to observe that there are two main entities in a CPS: the “cyber” end of the system that is composed of the hardware and software, and the “physical” end of the system that relates to part of the environment. The problem of designing the cyber part may not be trivial but can be solved from scratch. However, the physical part, usually a natural physical process, is inherently given and has to be identified in order to propose an appropriate cyber part to be adopted. Therefore, one of the first steps in designing a CPS is to identify its physical part. The physical part can belong to a large array of system classes. Among the possible candidates, we focus our interest on distributed parameter systems (DPSs) whose dynamics can be modeled by partial differential equations (PDEs). DPSs are by nature very challenging to observe as their states are distributed throughout the spatial domain of interest. Therefore, systematic approaches have to be developed to obtain the optimal locations of sensors to optimally estimate the parameters of a given DPS.

With this monograph, we wish to provide our reader with a comprehensive understanding of CPS and emphasize on our past experience in the topic. For the past five years, we have worked on the topic of optimal mobile sensing and actuation policies in CPSs and directed our research effort from purely theoretical results to more applicable results. That is why the reader will find not only sensing and actuation, but also remote sensing, an online solution to the problem of optimal sensing, and communication topologies.

We first review the recent methods from the literature as the foundations of our contributions. Then, we define new research problems within the above optimal parameter estimation framework. Two different yet important problems considered are the optimal mobile sensor trajectory planning and the accuracy effects and allocation of heterogeneous sensors. Under the remote sensing setting, we are able to

determine the optimal trajectories of remote sensors. The problem of optimal robust estimation is then introduced and solved using an interlaced “online” or “real-time” scheme. Actuation policies are introduced into the framework to improve the estimation by providing the best stimulation of the DPS for optimal parameter identification, where trajectories of both sensors and actuators are optimized simultaneously. We also introduced a new methodology to solving fractional-order optimal control problems, with which we demonstrate that we can solve optimal sensing policy problems when sensors move in complex media, displaying fractional dynamics. We consider and solve the problem of optimal scale reconciliation using satellite imagery, ground measurements, and unmanned aerial vehicles (UAVs)-based personal remote sensing.

Finally, to provide the reader with all the necessary background, the appendices contain important concepts and theorems from the literature as well as the MATLAB codes used to numerically solve some of the described problems.

Columbus, IN, USA
Logan, UT, USA

Christophe Tricaud
YangQuan Chen

Optimal Mobile Sensing and Actuation Policies in
Cyber-physical Systems

Tricaud, C.; Chen, Y.

2012, XVIII, 170 p., Hardcover

ISBN: 978-1-4471-2261-6