

Preface

Passivity is an input–output property of dynamical systems. The concept generalizes physical systems that cannot store more energy than the energy supplied from outside the system. It is one of the most physically appealing concepts in systems and control theory and has been used as a fundamental design tool for linear and nonlinear systems. The concept has also been used to achieve outstanding success in robot control, including the control of robot manipulators, mobile robots, and bipedal robots.

Despite the long history of passivity and passivity-based control, the approach still remains in active use even in new research fields at the intersection between systems and control and robotics. A typical new research field in which passivity plays a central role is networked robotics, where a robot works as a component of a network. In this book, we focus on three research fields that fall within networked robotics in particular, bilateral teleoperation, vision-based control/estimation, and cooperative control/estimation. The goal of this book is to describe a unifying passivity-based approach for the emerging research fields.

We consider bilateral teleoperation in Part I (Chaps. 2–4), which involves a dual robot system where one remote robot (i.e., slave) tracks the motion of another robot (i.e., master) that is commanded by a human operator. This field has wide applicability in areas such as operations in hazardous environments, undersea exploration, robotic surgery, and drilling. Some of the fundamental challenges in bilateral teleoperation are enhancing a robot’s ability to interact with arbitrary human operators and remote environments in a stable manner, conducting bilateral teleoperation over unreliable communication networks, and guaranteeing the transparency and high level of performance of the overall system. In this part, we demonstrate that passivity-based control can be utilized as a unifying methodology to address these challenges.

In Part II (Chaps. 5–7), we examine how passivity is utilized in vision-based 3-D rigid body motion control and estimation. The visual feedback process is known to include the projective property from 3D to 2D which has prohibited direct applications of the passivity-based approach for a long time. To address this issue, we present a novel motion estimation mechanism called a visual motion observer based

on the inherent passivity in rigid body motion. The observer enjoys the flexible extendability inherent in the passivity approach in terms of interconnections with passive components like robot manipulators and object motion models while ensuring the overall stability of the interconnected systems.

As discussed in Part III (Chaps. 8–11), cooperative control and estimation treats a network consisting of multiple agents with distributed decisions and local inter-agent interactions. In this research field, researchers explore how to design distributed control/estimation strategies using only local information so that the total networked system aggregating all of the dynamical components achieves specified group goals. Potential applications include robotic networks, sensor networks, and energy management systems. In this book, we mainly focus on the most fundamental but widely extendable group goal, namely output synchronization, which means the pairwise convergence of the agents' outputs. We reveal the role of passivity in achieving the group goal. As extensions of output synchronization, we also discuss attitude synchronization, pose synchronization, flocking control, and cooperative estimation.

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