Chapter 3
Hybrid DES and Continuous Models for Cyber-Physical Ubiquitous Environments

Ashish Gupta
http://orcid.org/0009-0002-4460-6605
Institute of Technology and Management, Gwalior, India

Ergashev Nuriddin Gayratovich
http://orcid.org/0000-0002-8274-6193
Karshi State Technical University, Karshi, Uzbekistan

Gafur Namazov
Termez University of Economics and Service, Termez, Uzbekistan

Buriboev Tolibjon Mirali Ugli
Alfraganus University, Tashkent, Uzbekistan

Olim Tursunov
Tashkent State University of Economics, Tashkent, Uzbekistan

Temur Khudayberganov
http://orcid.org/0000-0003-0248-3619
Urgench State University Named After Abu Raykhan Beruni, Urgench, Uzbekistan

Anorgul Ashirova
Mamun University, Khiva, Uzbekistan

Deepak Gupta
http://orcid.org/0000-0003-3929-1362
Institute of Technology and Management, Gwalior, India

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ABSTRACT

Cyber-physical systems (CPS) operating in ubiquitous environments combine continuous physical dynamics with discrete event-driven control in ways that strain conventional simulation tools. This chapter examines hybrid modeling methods that join Discrete Event System Specification (DEVS) with continuous-time techniques—principally Quantized State Systems (QSS) and co-simulation frameworks—for the design, analysis, and validation of such systems. Key concerns include embedding these models within IoT platforms, smart grids, digital twins, and healthcare applications, as well as managing actuation conflicts and event-driven synchronisation across heterogeneous device networks. Drawing on recent work in the literature, the chapter develops a layered reference architecture and identifies open research problems in distributed hybrid simulation, formal verification, and physics-informed machine learning for pervasive CPS settings.

1. INTRODUCTION

Cyber-physical systems occupy an unusual position in engineering practice: they are simultaneously software artefacts and physical machines, and their correctness depends on both the logic of their programs and the dynamics of the processes they govern. Over the past decade, the proliferation of networked embedded hardware—what is broadly called the Internet of Things—has stretched this dual nature across enormous scales. The digital transformation of economies and industries has further accelerated this growth, as networked devices become integral to supply chains, financial services, and urban infrastructure (Zayniddinov et al., 2025; Kulmanov et al., 2025). A single smart-building installation may integrate thousands of temperature, occupancy, and power sensors alongside hundreds of actuators, each issuing commands on its own schedule and each capable of disturbing the physical state in ways that other devices did not anticipate (Pradeep & Kant, 2022; Capocchi et al., 2025b).

Simulation has long been the primary tool for managing this complexity before hardware is committed. The trouble is that the simulation world