International Journal of Cyber-Physical Systems
Volume 1 • Issue 2 • July-December 2019

Architectural Modelling of Cyber Physical Systems Using UML

K. Sridhar Patnaik, Birla Institute of Technology Mesra Ranchi, Ranchi, India
https://orcid.org/0000-0002-4994-4489

Itu Snigdh, Birla Institute of Technology Mesra Ranchi, Ranchi, India

ABSTRACT

Cyber-physical systems (CPS) is an exciting emerging research area that has drawn the attention of many researchers. However, the difficulties of computing and physical paradigm introduce a lot of trials while developing CPS, such as incorporation of heterogeneous physical entities, system verification, security assurance, and so on. A common or unified architecture plays an important role in the process of CPS design. This article introduces the architectural modeling representation of CPS. The layers of models are integrated from high level to lower level to get the general Meta model. Architecture captures the essential attributes of a CPS. Despite the rapid growth in IoT and CPS a general principled modeling approach for the systematic development of these new engineering systems is still missing. System modeling is one of the important aspects of developing abstract models of a system wherein, each model represents a different view or perspective of that system. With Unified Modeling Language (UML), the graphical analogy of such complex systems can be successfully presented.

KEYWORDS

Architecture, control, CPS, design, IoT, model, System, UML

1. INTRODUCTION

According to Robert Minerva (Larrucea et al., 2017), "IoT as made out of networked sensors and smart objects whose purpose is to measure/control/operate on an environment in such a way to make it intelligent, usable, and programmable and capable of providing useful services to humans". And cyber-physical systems (CPSs) or "smart" systems as "co-engineered interacting networks of physical and computational components. CPS technologies include the IoT, Industrial Internet, Smart cities, Smart grids, and "smart" anything (for example, cars, buildings, homes, manufacturing, hospitals, and appliances).The thin line difference between IoT and CPS is IoT include those situations in which smart objects or things interact with their environment intelligently and provide value to stakeholders or customers. So, all these aspects should be taken into account from a software engineering perspective. Identified objects in an IoT system can still be networked together so as to control a certain scenario in a coordinated way, in which case an IoT system can be considered to grow to the level of a CPS. The IoT is seen as an enabling technology for CPS or CPSoS (System of Systems) (Xabeir et al., 2017; Borja et al., 2017; Reggio, 2018; Thramboulidis & Foradis, 2015). The merging of IoT and CPS into closed-loop, real-time IoT-enabled cyber-physical systems is seen as an important future challenge.

DOI: 10.4018/IJCPS.2019070102

Cyber-Physical Systems can be considered as the next general of Embedded Systems (Quadri et al., 2015). In recent years, the growth of connected Cyber-Physical Systems (CPSs) and Internet of Things (IoT) devices has increased tremendously due to the availability of high-capacity networks (3G and 4G/LTE networks), advanced sensors (e.g. RFID, NFC, etc.), protocols (e.g. IPv6, MQTT, etc.), mobile Internet and wearable devices. This paradigm shift will accelerate in coming years to drive the next technological revolution for CPSs, where a plethora of light-weight interconnected devices will be able to interact, communicate and share vast amounts of data (Quadri et al., 2015).

The spread of IoT (Internet of Things) (Afzaal & Zafar, 2017; González Bustamante et al., 2014; Gupta et al., 2016; Hafidh et al., 2017; Thramboulidis & Foradis, 2017) categorized into a type of cyber-physical system makes future systems larger and more complex than ever. Various components such as cloud services, edges, devices and energy suppliers play important roles when constructing an IoT system. Moreover, components in such systems have various relationships to other components. Hence, a simple specification notation for grasping such relationships is sought for architectural design of IoT systems.

As far as the examples (Jiang, 2018; Tan et al., 2018; Yu et al., 2012; Karsai & Sztipanovits, 2008) of cyber-physical systems are concerned, let us consider a driverless car that is proficient of sensing its environment and moving with little or no human intervention. These autonomous cars have variety of sensors to perceive their surrounding environment like radar, computer vision, sonar, GPS etc. Advanced control systems take sensory information to identify proper navigation paths, as well as obstacles and relevant traffic or road signs. Another example is a medical monitor or physiological monitor is a medical device used for monitoring. It consists of one or more sensors, processing components, display devices as well as communication links for displaying or recording the results elsewhere through a monitoring network. The monitoring may be cardiac monitoring, blood glucose monitoring, neurological monitoring etc.

The designing of such systems is impossible with the classical approach (Karsai & Sztipanovits, 2008) – the design of the physical and computational aspects is an integrated activity. Since design is a creative process involving design decisions, hence design made in one phase (e.g. selecting the scheduling technique used in the embedded software) interacts with the physical component and has intense significances on the dynamic properties of the whole system. It has been debated that the design of such systems could only be accomplished by taking an integrated perspective and co-designing the physical with the computational part.

A general or unified architecture plays an important part in the process of CPS design. This article introduces the architectural modeling representation of CPS which captures the essential attributes of a CPS. Despite the rapid growth in IoT and CPS a general principled modeling approach for the systematic development of these new engineering systems is still missing. System modeling is the process of developing abstract models of a system, with each model presenting a different view or perspective of that system. System modeling plays an important role in representing a system using some kind of graphical notation, which is now almost always based on notations in the Unified Modeling Language (UML). The importance of the architectural system modeling has led to development of OMG SysML (Karsai & Sztipanovits, 2008; Feiler et al., 2006; Holt & Perry 2008) widely used for systems engineering, and Architecture Analysis and Design Language (AADL) (Karsai & Sztipanovits, 2008; Feiler et al., 2006; Holt & Perry, 2008), Modelica (Graja et al., 2018), MontiArc (Ringert et al., 2015) for modeling of hardware and software architectures in embedded systems (Zhu et al., 2014).This helps the analyst to understand the functionality of the system and models are used as a part of communication tool with stakeholder or customers. The different perspectives of system modeling are: An external perspective, where we model the context or environment of the system. An interaction perspective, the focus will be on the interactions between a system and its environment, or between the components of a system. A structural perspective captures the organization of a system or the structure of the data that is processed by the system. A behavioral perspective, where we model the dynamic behavior of the system and how it responds to events.