Chapter 15
Bayesian Model for Evaluating Real-World Adaptation Progress of a Cyber-Physical System

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ABSTRACT

Cyber-physical systems, also known as CPS, have come to stay. There is no doubt, CPS would one day outnumber humans in industries. How do we evaluate the adaptation progress of these systems considering changing environmental conditions? A failed implementation of a CPS can result to a loss. Since CPSs are designed to automate industrial activities, which are centred on the use of several technologies, collaboration with humans may sometimes be inevitable. CPSs are needed to automate several processes and thus help firms compete favourably within an industry. This chapter focuses on the adaptation of CPS in diverse work environment. Considering the ecosystem of the CPS, the authors present a Bayesian model evaluating the progress of adaptation of a CPS given some known conditions.

INTRODUCTION

Cyber-physical systems (CPSs) focus on integrating computational applications with physical devices designed as linkages of collaborating cyber and physical components. Powered by data, these systems are considered intelligent and have the ability of automation. There is no doubt, CPS would one day outnumber humans in work environments. How do we evaluate the adaptation progress of these systems considering ever-changing environmental conditions?

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As new technologies are introduced in an Organization, several practices change in other to adjust to the new work environment. CPS is designed to seamlessly fit into its environment in the shortest time possible and serve to reduce the cost of production, optimize production, and ensure efficiency in an organization. However, a failed implementation can result in a loss or a total closure of an organization. In addition to its implementation problem, interaction with humans may also pose a challenge. A general situation or condition of humans, activities including the facilities or equipment needed, and the environment of the activities are three fundamental factors influencing the adaptation of CPS (Chang. et.al, 2012).

Since CPSs are designed to automate industrial activities that are centered on the use of several technologies collaboration with humans may sometimes be inevitable. In such situations, CPSs may include features designed to support adaptation in a dynamic environment. According to research, challenges of adaptation increases in Industries with broadband structure (Panetto et.al, 2019).

The goal of this chapter is to provide a mathematical framework that will serve as a guide in developing Bayesian models to monitor the adaptation progress of CPS in industries.

In the past, automation was concentrated on some few business processes while the majority of processes are left unautomated. This however has changed due to the changing environment and the dire competition within industries. The need for optimization, which includes; production cost reduction, process efficiency, improved customer satisfaction/loyalty, reduction of waste, increased profitability (Niedermann and Schwarz, 2011), has led many industrial key players to opt for automation. Despite the importance, automation introduces, many industrial players are still skeptical about the idea of leaving the control of their business to CPSs. This, however, is about to change as the new industrial revolution (industry 4.0) powered by data and CPSs take over. Another driving technology of CPS is IoT. In time past the internet transformed communication and collaboration in many businesses, in these present times, the internet is not only influencing communication but also powering decisions in several industries. The IoT is a clear example of such usage of internet infrastructure to power Just-in-time production supporting a pull-based demand.

As businesses harness the power of data/information, CPSs are needed to automate several processes and thus help firms compete favorably within an industry. Considering the complexity in human behavior and the successful implementation of the Bayesian network in the prediction of human behavior, a Bayesian model can effectively be designed to predict the probability of an event given some known conditions (conditional probability). Considering known processes available within an industry, the progress of adaptation can be evaluated. This chapter follows are score-based approach in evaluating the rate of learning (adaptation) of a CPS given some known conditions. Evaluating the adaptation process of CPS will go a long way in achieving a wider adoption of CPS and the technologies they power. Some key challenges of adoption are, real-time control, real-time SOS, modularization of CPS, etc… These adoption challenges relate to adaptation problems and will be elaborated upon in this chapter. Another aspect to consider in adaption is the specific business process or sets of processes being automated. The more intertwine (cross-functional) a process is the more complex adaptation would appear. As processes move from one functional department to another, information is transferred from one CPS process to another and this calls for a control mechanism. The CPS ecosystem is designed to handle whatever complexity that may arise from communication between the CPS and its environment. In understanding adaptation, the ecosystem (Frame) is important and would be discussed briefly in this chapter.

The chapter is organized as follows. We started by reviewing some related literature, then we presented an overview of CPS and different terminologies needed in understanding its operations, next section

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