Chapter 1
Advanced Technology for Cyber-Physical System Monitoring

Man Tianxing
https://orcid.org/0000-0003-2187-1641
ITMO University, Russia

Vasiliy Yurievich Osipov
https://orcid.org/0000-0001-5905-4415
Saint Petersburg Institute for Informatics and Automation of Russian Academy of Sciences (SPIIRAS), Russia

Ildar Raisovich Baimuratov
ITMO University, Russia

Natalia Alexandrovna Zhukova
Saint Petersburg Institute for Informatics and Automation of Russian Academy of Sciences (SPIIRAS), Russia

Alexander Ivanovich Vodyaho
Saint Petersburg Electrotechnical University (LETI), Russia

Sergey Vyacheslavovich Lebedev
https://orcid.org/0000-0002-0045-6310
Saint Petersburg Electrotechnical University (LETI), Russia

ABSTRACT

In the chapter, the problem of cyber-physical systems monitoring based on the processing and evaluation of the data received from the observed objects is considered. The main attention is paid to finding a suitable way to reduce the synthesis complexity of the observed objects models and monitoring processes. The authors propose a multilevel automatic synthesis technology that formalizes such models to multilevel relatively finite automata. The architecture of cyber-physical monitoring systems using this technology is presented.

INTRODUCTION

The Cyber-Physical System (CPS) is a multi-dimensional complex system that implements real-time perception, dynamic control and information service for large engineering systems through 3C (Computation, Communication, Control) technologies. These systems can contain a considerable number of

DOI: 10.4018/978-1-7998-1974-5.ch001

interconnected objects. The CPSs make different decisions and controls based on monitoring the real-time state of the observed systems through a large number of sensors. However, the data obtained by the underlying physical components are redundant, massive, and uncertain (Wolf, W. H. 2009). These systems typically are not smart enough to extract information from large amounts of input data.

To address these critical issues, in recent years, researches have been focused on intelligent cyber-physical monitoring systems (CPMS) that are CPS systems with intelligent abilities oriented on solving monitoring tasks. Such systems are based on models, methods, and technologies of artificial intelligence (AI). They can analyze and interpret acquired data and activate proper reaction/control mechanisms to guarantee the quality of monitoring results.

In the researches about the building of CPSs, most of the attention is paid to the synthesis of programs (Gulwani, S., et al. 2017). There is no known effective solution for the synthesis of models of complex observed objects. The modern approaches to model synthesis don't allow synthesizing models that allow solving CPS monitoring tasks. For now, the most reliable way to solve the synthesis problem is to develop the ideas of model synthesis within the symbolic approach.

Model synthesis in CPS can be based on models and methods proposed in (Osipov V. Yu., 2016). It assumes building single-level models using deductive synthesis methods. However, it cannot be directly used for model synthesis in CPS because of the high computational complexity. The complexity can be significantly reduced due to the transition from single-level to multi-level models. Attempts to build such multilevel models in program systems revealed a considerable number of problems. To solve them it is necessary to state the problem, to develop formal models and methods, define new technology of data processing and evaluation. It is expected that new multilevel systems can overcome the drawbacks of existing single level systems.

In this chapter, the general ideas of multilevel monitoring are considered. These ideas are translated into a multilevel automatic synthesis technology which includes new methods for multilevel synthesis of objects and systems, processes and programs for monitoring based on the results of data processing. For processing monitoring data, a new ontology-based knowledge model is proposed. At last, the architecture of the CPS monitoring system using the proposed technology is presented.

BACKGROUND

Cyber-physical systems operate alongside, for the benefit of, and supported by humans. The approaches to modeling and reasoning about human involvement in socio-cyber-physical systems (SCPS) have become a popular topic (Calinescu, R. C., et al. 2019). Zavyalova, Y. V., et al. (2017) combined this concept with the cyber-medicine system to discuss the development of smart spaces-based socio-cyber-medicine systems. Smirnov, A., et al. (2017, June) addressed context-aware decision support in agent-based environments for smart space-based systems and human-computer cloud services. This method deal well with the highly decentralized up-to-date data sets arriving from various resources located in socio-cyber physical systems.

Most of the existing monitoring systems use intelligent components that are aimed to solve analytical tasks and visualize data (Albahri, O. S. 2018). By now a considerable number of such components have been developed, including Zabbix Monitoring (Dalle Vacche, A. 2015), Pentaho Reports (Gorman, W. 2009), Google Analytics (Plaza, B. 2009) and so on (Nasle, A. 2017; Luo, H. 2015).