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A Literature Review of Cyber-Physical System Applications

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ABSTRACT: ***A new generation of digital systems, the Cyber-Real System (CPS), focuses on intricate interdependencies and integration between cyberspace and the physical world. Because of their potentially substantial effect on society, the environment, and the economy, cyber-physical systems (CPS) are presently of interest in academia, business, and government. A CPS is made up of tightly coupled computing, communication, control, and physical components. Academics, business, and government are all interested in CPS right now. However, there is no systematic and comprehensive overview of CPS research. As a result, this article performs an extended literature analysis on CPS applications by analyzing existing literatures in the Scopus database from 2012 to 2017. In particular, 77 articles on CPS applications are categorized and evaluated into ten categories. The contents of each research category's articles are summarized. The difficulties and tendencies of CPS research are also shown.***

KEYWORDS: ***Cyber Physical System, Eco-System, Intelligent Transportation, Simulation, Systematic Review.***

INTRODUCTION

Since 2006, the National Science Foundation (NSF) has provided significant funding for CPS research. UC Berkeley, Vanderbilt University, University of Memphis, University of Michigan, University of Notre Dame, University of Maryland, and the General Motors Study and Development Center are among the institutions and institutes that have joined this research field[1]. CPSs have been regarded as a new development approach by the US government since 2007. Simultaneously, academics from various nations have begun to recognize the importance of CPS research. Since 2008 and 2010, many conferences and seminars on CPS have been held, including the CPS Week and the ACM/IEEE International Conference on Cyber-Physical Systems (ICCPS). The Cyber Space Platform (CPS) is a new generation of digital system that consists of two main functional components: (1) advanced connectivity, which ensures real-time data acquisition from the physical world and information feedback from the cyber space; and (2) intelligent data management, analytics, and computational capability, which constructs the cyber space. The usage of CPS seeks to improve the flexibility, autonomy, efficiency, functionality, dependability, safety, and usability of large-scale systems, thus increasing their implementation. Theoretical underpinnings and applied studies on CPS may be divided into two groups. Although progress has been achieved in modeling, system design, technology implementation, and real-world applications, CPS research is still in its infancy[2]. Many papers look at the present state of CPS research. However, there is no systematic and comprehensive overview of CPS research. As a result, this article performs an extended literature analysis on CPS applications by analyzing existing literatures in the Scopus database from 2012 to 2017. Specifically, 77 articles examining CPS applications have been categorized and evaluated into ten categories. The contents of each research category's articles are summarized[3]. The difficulties and tendencies of CPS research are also shown. Although CPS has been in use from the early 1970s, Helen Gill of the National Science Foundation in the United States invented the word CPS in 2006, and the phrase "cyber-physical system" was not coined until 2006 "was a term used to describe systems that linked the physical and digital worlds (Lee, 2015). CPS has been characterized by the scientific community from a variety of

viewpoints so far. Scholars have undertaken research from many angles based on these conceptualizations of CPS to investigate the function of CPS and the difficulties it faces in the information age. Introduce the history of CPS, its connections to various areas of study, and practical applications in Smart Manufacturing, Emergency Response, Air Transportation, Critical Infrastructure, Health Care and Medicine, Intelligent Transportation, and Robotic for Service in a systematic manner. A review of the literature on techniques for assessing interoperability in CPS. They found no evidence of industry adaption of these models after reviewing 42 publications and 24 distinct interoperability assessment models, and they ascribe this to a lack of validation in the context of CPS development. Existing research on CPSs, on the other hand, is disjointed, fractured, and dispersed[4]. There is a need for a thorough and comprehensive assessment of current CPS research. As a result, this study builds on previous research by using the Scopus database and performing a more comprehensive literature analysis on CPS applications. This study examines 77 journal and conference papers on CPS applications in the Scopus database from 2012 to 2017. Agriculture, education, energy management, environmental monitoring, medical devices and systems, process control, security, smart city and smart home, smart manufacturing, and transportation systems are among the ten research categories. The specifics of these study categories. The purpose of this article is to evaluate the existing literature in the field of CPS applications by categorizing it and determining the research trend in CPS. Scopus is the world's biggest citation database, with over 15,000 peer-reviewed journals from over 4000 publishers indexed. The terms "Cyber Physical System," "Cyber-physical Systems," "Cyber Physical Systems CPSs," "Cyber-physical Systems CPS," and "Application" are used in this research "as the keywords used to search Scopus databases for published articles from January 2012 to March 2017[5].

Initially, a total of 118 articles are chosen. After eliminating extraneous topics, a total of 77 articles were selected as examples for this research[6]. Precision agriculture, intelligent water management, and more efficient food distribution are just a few examples of how CPS research can help the development of agriculture by increasing food consumption efficiency and overall food production capability through technologies like precision agriculture, intelligent water management, and more efficient food distribution. A maximum output is obtained in agriculture by constantly monitoring the environment and its effect on the crop. As CPS becomes more prevalent in our everyday lives, the demand for a well-trained workforce emerges, necessitating innovative methods and test-beds for incorporating CPS ideas into schools at all levels[7]. As our society evolves to rely more on CPS, education and training confront a number of difficulties. Model, simulate, and validate CPS using an extension of the synchronous programming language Quartz. They show how the Quartz programming language and the Averest toolset may be used to teach CPSs in a master's degree in computer science, emphasizing the need of combining lecture courses with practical exercises utilizing Averest tools for simulation and verification. Describe their experience teaching CPS through a series of course modules that depend extensively on modeling and verification to engage students in successfully building CPS apps while improving their knowledge of cognitively difficult concepts utilizing the popular Android platform. In the framework of a first-year class, a lecture and a lab experience are assigned to teach CPS principles[8]. This educational setting may assist students grasp the importance of CPS to IT professionals and offer them a taste of developing and working with CPS. A CPS that combines mechanisms for habit-based control, low-volume communications, and statistical analysis to create a smart university laboratory environment. The Mobile Open Platform for Experimental Design (MOPED), a learning laboratory environment for CPS, consists of a model car chassis equipped with a network of three control units based on standard hardware and running the automotive software standard

AUTOSAR, which consists of operating system, middleware, and application software structures, and running the automotive software standard AUTOSAR. It enables cloud connection, federated embedded system development, and continuous distribution of new features[9]. Because CPS is such a young field of study, there are few courses geared at advanced graduate students. Undergraduate students will take a CPS course. The course may assist students comprehend and master the contents without having a background in embedded real-time systems, advanced mathematics, formal verification, or control theory by teaching CPS basics[10].

DISCUSSION

A programming framework that enables students to use their internet browsers to build and test CPS control systems. Students use a web page supplied by the teacher to model and develop a CPS application at a high abstraction level. These studies on CPS in education show that studying each of the following topics separately is insufficient because a CPS is not their union but their intersection: embedded computers, control theory, sensor and communication networks, physical resources, decision theory, data fusion, knowledge discovery, resilience, and dynamic configuration. The atmosphere in which these components must be examined together should be provided through education. CPS stands for "distributed system." Despite the fact that the overwhelming majority of devices in CPSs need less energy, energy supply remains a significant issue due to inconvenient demand and supply. Energy-aware buildings reduce waste of electricity, water, and heat, resulting in resource conservation. One of the most powerful driving factors for the development of CPS is the smart grid.

The smart grid is now widely recognized as the next-generation electrical power system, capable of adaptive and optimum power production, distribution, and consumption. A novel CPS application for the energy management framework (EMF) that can gather real-time power consumption status and demand from autonomous electric vehicles (AEVs) and charging stations in the smart grid. In the context of a Wireless Sensors Network, their energy-efficient design approach incorporates real-time AEV route planning and event-based control (WSN). A distributed dynamic model for a type of data-attacked power systems. They propose dynamic state estimators for large-scale distributed systems that use a 9-bus power system to achieve optimum control. CPS for environmental monitoring, spread over a large and diverse geographical region (forests, rivers, and mountains), must operate for extended periods of time with low energy usage without human intervention. In the event of natural or man-made catastrophes, CPS can monitor the surrounding environment and react rapidly through a large number of sensor nodes in the areas. Because of external circumstances, the effect of CPS on the environment is critical. A comprehensive explanation of an open architecture that may be used to monitor the surroundings. Their architecture is based on WSN, multi agent, and cloud computing technologies and consists of three layers: a bottom layer consisting of several sensor nodes distributed over a large area and communicating through User Datagram Protocol messages; a middle layer containing the information acquired by the bottom layer, stored in a measurements database, the knowledge base used to provide decision analytic services; and a top layer consisting of several sensor nodes distributed over a large area and communicating through User Datagram Protocol messages.

In such a setting, the ad-hoc network's precise and real-time data gathering combined with its low power consumption provide a significant research challenge. By combining sophisticated sensing, communication, computing, and control technology with real-time information sharing, intelligent transportation may enhance safety, throughput, coordination, and services

in traffic management. Autonomous vehicles, which range from automobiles to trains to aircraft, have zero traffic fatalities. CPS is also very significant in the healthcare sector. Smart sensor systems for real-time patient health condition monitoring and warning, telemedicine systems that enable remote healthcare service provision, and semi-autonomous tele-operated home service robots that can assist with patient physical activities are among the CPS research topics in this category. Medical cyber-physical systems (MCPS) are rapidly being utilized in hospitals to offer high-quality continuous care for patients, but there are still a number of difficulties to overcome, including context-aware intelligence, autonomy, security and privacy, and device design. Incorporating cybernetics and information technology into the operating room.

They create a cyber-physical management system, which includes a robotic scrub nurse, to assist surgeons by passing surgical instruments as needed during surgery and documenting surgical instrument counts in a personal health record (PHR). They also find that, independent of the style viewer, this online health tool enables the transmission of clinical and surgical information to electronic medical record-based and PHR-based apps across various institutions. Some technical skills measurement based on a CPS for endovascular surgery simulation and conclude that the development of cyber-physical simulators for other domains of medicine is dependent on the study of photo elastic materials for human tissue modeling, which allows quantitative evaluation of skills using surgical instruments and a realistic representation of human tissue. In healthcare settings, combine active and passive user input modalities for knowledge discovery and acquisition. Individual active and passive real-time patient data may be utilized for enhancing clinical decision support, thanks to ontologies, terminologies, and textual patient records.

Future Cyber-Physical Medical Systems should include broad data integration and access, complete data collection and analysis, closed loop control capabilities, energy efficiency, real-time visualization, and plug-and-play compatibility with interoperable medical equipment, among other features. Embedded systems, real-time wireless networks, design and development methods for safety critical complex medical systems, and safety verification and validation may all help to speed up the continuous evolution of medical and healthcare systems toward safer, smarter, and more interconnected systems. Control loops in industrial process control systems are often utilized to give autonomous control over manufacturing processes.

Because CPS is often defined as the integration of computing with physical processes, improved process control is the most direct use of CPS in Industry 4.0 scenarios. Because CPS can combine all the methods to achieve and maintain a synchronized state, it may offer comprehensive controls over complex and massive industrial processes via a heterogeneous network architecture of sensors, actuators, and computers. By adjusting the durations of controller activities, system performance may be improved. Enterprise process cooperative scheduling and management based on dynamic enterprise modeling. This system obtains girder movement information using smartphones with inbuilt sensors and sends an alert message to the controller phone whenever the data exceeds a threshold, indicating that the method is convenient and feasible. CPS can offer such pervasive, energy-efficient, and low-cost capabilities by using information from the physical environment. They're complicated systems with complicated applications, and the actuators have a direct impact on the physical environment. As a result, one of the most significant problems that should be addressed in CPS is security, which has gotten a lot of attention in recent years. There are many unresolved problems in CPS system models and security designs. A short and quick assessment of the current literatures on security in CPS for next-generation wireless systems, identification of

important CPS characteristics, proposal of a prototype architecture with security management considerations, and additional discussion of these systems for security.

The delusion of assaults from the cyber layer to the physical system is captured by this generic model for CPSs. They offer a new method influenced by the behavioral framework of cognitive hierarchy theory to study the interactions between one defender and one attacker across a CPS using a game-theoretic approach. This generic method is applied to smart grid security, with implications for energy markets and wide-area protection. The information security property of noninterference and its iteration composition in CPS introduces a novel formal technique for investigating the information security property of noninterference, as well as a sufficient and necessary condition of noninterference iteration composition in CPS. CPS may be disrupted as a result of security assaults, resulting in significant social and economic costs.

Due to the diversity of attack surfaces from cyber and physical components, as well as frequently limited computing and communication resources, constructing a secure CPS is especially difficult. A resource-constrained CPS design framework with a cross-layer design framework. The framework integrates control-theoretic approaches at the functional layer with cybersecurity techniques at the embedded platform layer, addressing security alongside other design criteria including control performance under resource and real-time constraints. Examine how monitor systems, which are often employed in Industrial Control Systems, may be vulnerable to cyber-attacks using the cyber-physical testbed created as part of the EU Project FACIES. For data extraction and synthesis, a systematic mapping study (SMS) was conducted to systematically identify 48 main Model-Based Security Engineering research. Their findings not only show that the SMS is the state of the art in MBSE4CPS, but they also highlight a number of open issues that need to be investigated further, such as the lack of engineering security solutions for CPSs, limited tool support, a lack of industrial case studies, and the difficulty of bridging DSLs in engineering secure CPSs. It's important to note that CPS security differs from cybersecurity. Because the cyber components of CPS need all cybersecurity procedures in addition to the other security protocols provided by the physical components and their interactions, CPS security is more essential than cybersecurity, and cybersecurity may be regarded a subset of CPS security.

CPS offers a wide variety of smart building appliances that open up new possibilities for smart city and smart home applications. An urban setting with a new generation of innovative services for transportation, energy distribution, healthcare, environmental monitoring, business, commerce, emergency response, and social activities is referred to as a smart city. A plethora of sensors are installed in smart houses to measure physical characteristics or more sophisticated data. The possibilities for this ecosystem are almost limitless. The goal of a smart house, smart building, or smart city is to offer us with pleasant living spaces. Smart cities improve public safety in general while also using smart transportation to alleviate traffic congestion. Some important demanding features of a Smart City are discussed, as are some lessons gained from seeing them as CPSs, and some basic research problems are outlined. He claims that a smart city is a CPS with new software platforms and stringent criteria for mobility, security, safety, privacy, and the processing of enormous quantities of data. This control center makes it easier for non-expert users to access all sensors, actuators, processes, and more sophisticated components represented by service robots by reducing the complexity of CPS with many control choices. The requirement to combine diverse widely dispersed devices into a single software environment is a significant issue in this application field. In the present environment, each new smart city and home application needs its own method of logging in and being available to its users.

What's missing — and what will determine the future — is an underlying common platform that will enable such apps to function as plug-and-play components in this environment. The major difficulties in the design of industrial systems are now widely recognized as modularity, and re configurability. The use of embedded software and hardware technologies to improve productivity in the production of products or the delivery of services is referred to as smart manufacturing. CPS has been used in a variety of fields and has made significant progress, although it is still in its infancy. Many contemporary cyber-physical applications need great reliability, safety, and security, as well as assured (ultra-)high performance and/or (ultra-)low energy usage. As a result, CPS applications face significant challenges in terms of security and privacy, efficiency, and interoperability. Due to its scalability, complexity, and dynamic nature, CPS is vulnerable to both physical and cyber failures and attacks. Other factors that make CPS vulnerable to security threats include the use of a large-scale network (such as the Internet), the adoption of insecure communication protocols, the heavy use of legacy systems, or the rapid adoption of commercial off-the-shelf (COTS) technologies.

CONCLUSION

The goal of this article is to offer academics and practitioners with a complete overview of CPS applications by conducting an exhaustive analysis of 77 publications regarding CPS applications from 2012 to 2017 gathered in Elsevier's Scopus database. There are ten research categories in which these articles are categorized. The contents of each research category's articles are summarized. Each study category's challenges and trends are also shown. Scholars may use this study to keep up with the newest CPS research and get research ideas. This research may also teach practitioners new methods and their effects. As a burgeoning study field, a slew of issues about CPS must be answered, at various levels of the architecture and from various areas of systems design, in order to initiate and facilitate the integration of the physical and cyber worlds. The fact that only the Scopus database was used is a significant drawback of our research. Several other significant CPS research fields, such as critical infrastructure control, distributed robotics, military systems, and aerospace systems, are not addressed in this article. To verify the findings in this study, future research should evaluate research on CPS based on additional databases, such as SCI/SSCI, IEEE Explore, and Google Scholar. Furthermore, this study solely looks at CPS applications; research into the theoretical underpinnings of CPS is not included. The advancement of CPS ideas and technology should be explored in future study.

REFERENCES

[1] C. W. Axelrod, “Managing the risks of cyber-physical systems,” 2013, doi: 10.1109/LISAT.2013.6578215.

[2] Z. Li, M. Shahidehpour, and F. Aminifar, “Cybersecurity in Distributed Power Systems,” *Proc. IEEE*, 2017, doi: 10.1109/JPROC.2017.2687865.

[3] R. J. Haberlin and Y. Y. Haimes, “Regional Infrastructures as Complex Systems of Systems: Shared-State Model for Regional Resilience,” *J. Infrastruct. Syst.*, 2018, doi: 10.1061/(asce)is.1943-555x.0000421.

[4] NIPP DHS, “Nipp 2013,” *Dhs*, 2013.

[5] P. E. J. Green, *Enterprise Risk Management: A Common Framework for the Entire Organization*. 2015.

[6] A. Latto, “Managing Risk from Within,” *Risk Manag.*, 2007.

[7] D. Engelbertink, S. Woudstra, H. Schiele, and M. Msc Msc Frederik Vos, “Managing the influences and risks of Industry 4.0,” *Univ. Twente, Fac. Behav. Manag. Soc. Sci.*, 2017.

[8] P. A. S. Ralston *et al.*, “Cyber Essentials Scheme,” *Comput. Secur.*, 2014, doi: 10.1109/INDIN.2013.6622963.

[9] R. Egert, C. G. Cordero, A. Tundis, and M. Mühlhäuser, "HOLEG: A simulator for evaluating resilient energy networks based on the Holon analogy," 2017, doi: 10.1109/DISTRA.2017.8167665.

[10] B. J. KIM, "The Use of Robo-Advisers and the Protection of Financial Investors -Focusing on Implications of the U.S. Regulatory Frameworks-," 법학연구, 2017.