BIG DATA IN HETEROGENEOUS CYBER PHYSICAL SYSTEMS: A REVIEW

Vishali Sivalenka¹, Srinivas Aluvala², Khaja Mannanuddin³

¹Department of Computer Science & Engineering, Sumathi Reddy Institute of Technology for Women, Warangal, India
²Department of Computer Science & Engineering, S R Engineering College, Warangal, India
³Department of Computer Science & Engineering, Sumathi Reddy Institute of Technology for Women, Warangal, India

¹vishali.sivalenka@gmail.com, ²srinu.aluvala@gmailcom, ³khajamannan@gmail.com

Corresponding Author: Vishali Sivalenka

https://doi.org/10.26782/jmcms.2020.08.00032

Abstract

Today, in the technologized generation the utilization of smart computing devices has been increasing with a rapid pace in every walk of life, such as the adoption of smart watches, fitness bands, diabetic actuators, automatic machines and digital medical equipment for personal and organizational activities. In all these areas from personal to organizational and medical to satellites, the networking of devices and data transfer plays a key role. The autonomous networked computing system, that connects the physical and software components together to access, analyze and process the data for computing, communicating through networking is known as Cyber Physical System (CPS). When these systems used in different areas, they access and process a voluminous data called big data. As the big data is increasing in a large volume day by day, it has become challenging to handle such gigantic data in Cyber Physical System. So, there evolved a need to develop different tools and techniques to handle the big data in various Cyber Physical Systems. Focus of this review is to present the various tools and techniques used to manage big data in heterogeneous Cyber Physical Systems, in addition to this, it also briefs the growth and applications of Cyber Physical System.

Keywords: Big data, Cyber Physical System, Data Analytics.

I. Introduction

Now a days, the evaluation of information and communication of the systems with other systems over the internet can be measured fast with low cost.
transmission and evaluation capabilities of data are increased in the systems to organize a large amount of data in all types of physical atmosphere. The growth of social media applications and their financial profits are created by acquiring the capabilities such as speed and accuracy of the systems. So, they require the systems those help in computing and communications with the physical atmosphere as Cyber Physical Systems [XVI].

Cyber Physical System (CPS) connects the physical world with software components and facilitates the accessing and processing of data through internet by unifying the physical processing, computing and networking. The operations of CPS are supervised, managed and combined by many complex algorithms along with computational entities [XLV].

CPS transforms the interactions among the humans and controls the physical world around us same as the internet transforms the interactions and communications among the humans and their internet access for online e-commerce transactions, banking transactions etc.

The mechanism is based on multiple disciplinary systems like computer communications systems, collaborative systems etc. and the software is developed in such a way that to provide the evaluation and communication capabilities in all aspects of physical atmosphere [XI] [XVI].

The CPS has evolved a large voluminous data referred to as big data. This huge data helps in increase the financial status of many business organizations by recognizing the product needs of consumers and provide the best services to them. The storage and organization of such enormous and complex data became challenging to the traditional systems. So, the modern technologies such as cloud and fog computing, Internet of Things (IoT), mining of data, machine learning etc. are used to store, process, evaluate, reveal the concealed patterns and unrevealed associations among the data [XVI]. In [XXVIII], the properties of big data are defined in the introduction part of the document. The relevance of CPS and the big data generation is similar to achievement of universal sustainability objectives [XXVII] [XLVII] [XLV].

II. The Exploring the Germination of Cyber Physical System

The people who work together with computers and machines can achieve the goals by using Computation, communications, and control (CCC) technologies. The National Science Foundation’s (NSF) Helen Gill invented the term CPS in 2006; the Cyber Physical System’s CCC core technologies have a great antiquity. In 1868, the control theory was invented, in 1903, wireless telegraphy was invented, feedback of cybernetics in 1948, in 1961, the embedded systems, software engineering in 1968, and ubiquitous computing in 1988 [VII].

Cyber Physical Systems are extending to digital ecosystems with its increased intelligence. So, it can be easily accessed in the cloud due to analyzing and fast learning. The utilization of Cyber Physical Systems increases more than that of
today’s as they affect each system by their interconnected capability, flexibility, extensibility, durability and providing safety and security.

The main aim of CPS research program of NSF is the development of core systems science to build compound Cyber Physical Systems. The fundamental principle of CPS is to access the specific systems and their application domains [XXIV].

There evolved a large research scope in prototypes development and framework modelling of Cyber Physical Systems [XXI] [XIX] [XX]. Many research societies have established to work for the feature of CPS software engineering aspect such as conferences and workshops of CPS like CPS Week, software engineering for adaptive and self-managing systems (SEAMS) [XLVI], Models@run.time [XLII] [XL] along with runtime validation, verification, and certification techniques [XXXII].

Since 2010, the NSF, NIST, the National Institutes of Health [NIH], EU Horizon 2020, and Europe 2020 have visualized their research on implementing the CPS applications. Their vision is that the IT revolution has less transformation when compared to CPS revolution for past 40 years [XXII] [XLIII].

CPS is in the centre point of technology. The CPS technology relates to embedded systems, the Industrial Internet (II), the Internet of Things (IoT), Smarter Planet, machine-to-machine (M2M), the Internet of Everything (IoE), cyber-physical-human systems (CPHS), Industry 4.0, adaptive systems, intelligent and smart systems which have their own community publications [XXIV].

In international conference and CPS week, the different countries researchers explained the need, implementations and various technologies, problems of CPS [XIV]. In [IX] [XIII] [VIII] [XXX], the presenters conveyed their interest in CPS research along with its limitations, implementations, design etc. The latest research on CPS evolves the increase of CPS utilization in different areas like power consumptions, real time applications, transmission and management of data, its security, allocation of resources etc. They also compared the advantages and features and modelling progress of CPS with other electronic systems [XXXI].

Global Cyber Physical System Market valued just about XX billion USD in 2017, it is anticipated to grow with a healthy rate of over cardinal that is forecasted in the years 2018-2025. The Cyber Physical System Market is incessantly growing across the globe over the approaching years. The most important driving issue of the worldwide Cyber Physical System market area unit increasing adoption of the net of Things (IoT) and increasing expenditure on the System of crucial infrastructure by organizations. Additionally, the swelling economic process of many developing countries is boosting the market growth of the worldwide cyber physical System market. Cyber Physical System into AN industrially applicable field, making vital opportunities within the international Cyber Physical System market. However, the most important factors that limiting the worldwide cyber physical System market growth area unit need high skilful force and dearth of System related to these systems [VI].

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Different CPS Big Data Sources

The two different CPS big data sources are: context computing and social computing.

Context Computing and Communications

Context refers to the information description and present status of an entity or group or entities. It is defined in many ways in several contexts for various users. The entities are defined as concrete and virtual entities. In recent years, the development of modern networks and communication technologies are improving on the internet. Their functionalities and complexities are also becoming more complicated. So, context-aware communication and networking (CACN) systems and their applications been evolved. CACN functionalities will also be used in ICTs i.e., Information and Communication Technologies. CACN can be executed in all communication and networking layers. Context information can be defined in many ways like information of space, different levels of batteries, status of networks, power consumptions, parameters of environment etc. [XXVI].

The data that is collected by sensors for its specific application usage is known as raw data. Without any further processing, the raw data is collected directly from the environment. The analysis and interpretation became challenging with raw data. So, the sensors use context aware computing to make meaningful and easily interpretable big data. The sensors store easily understandable processed meaningful information called context information [XXVI], [XXXIV]. For example, the data which is collected by the medical sensors from the readings of blood sugar from a diabetic patient is considered as raw data whereas after processing these readings, the report can be generated consisting of patient’s sugar levels, such data is considered as context information. The standard, valid, accurate and up-to-date context information is estimated by the quality of context (QoC) metric [XVI]. Context information is accessed by the sensors such as logical, virtual and physical, a middleware infrastructure or directly by accessing the preferences of users. The context information is divided into two types as per how the data is acquired. They are primary context where the data can be had directly from the different parts of the industrial plants and the secondary context is getting the same data from the plant's database [XV].

Social Computing

Social Computing provides the facilities to simplify the social interactions among the users with computational devices. Websites can be used to interact among the users and the social computing is used in government, business and organizations [XXXVI]. Mobile data is growing day by day as the smartphones usage is drastically increased by transferring a large amount of data among the users and their applications, data performance in network, profiles of subscribers etc. [XXXV]. The big data in mobiles can be referred to as mobile big data which has unique characteristics. One of the characteristics is that it divides the mobile data into time and space like hours, minutes, seconds etc. For example, the group of subscribers’
requests at a certain time and location, simultaneously, according to the similar behavior or mobility patterns, they can optimize the performance of the network [XLVIII]. Social computing integrates the web technologies with social performance and circumstances. It assumes that the social dynamics can perform the operation to make social wireless network planning and maintenance easy [XXXIX], [XXXVII]. Social computing helps in detecting the infectious diseases, analysis and predicting of emergency evolution. By this, it can help in protecting the public health [XXXIX].

III. Implementations of Cyber Physical System in Various Fields

The different applications of big data in various Cyber Physical Systems are: Smart Grids, City management, Disaster events applications etc. For example, the intelligent transportation system will produce the information about the behavior of a driver, information of passengers, positions of vehicles, managing of traffic signals, reporting of accidents, accounts of automated charges etc. Every CPS application generates a huge amount of data that is to be saved, managed and evaluated to upgrade the services and performance of applications.

Smart Grids

Smart grid comprises of standard energy utilization and becoming popular as they have high sensing and signal processing technology. The huge data is generated when the sensors of home appliances communicate with sensors of large number of power generators. These sensing and controlling technology in smart grids limited to a small city after that they have expanded to the broad are such as to the whole country. So, the utilization of smart grid helps in handling more data that is 22 gigabytes of two million customers per day [XXV]. Hence smart grid applications use the big data tools such as cloud computing [LII], analytics and mining [III] [XXIX], optimizations [XXXIII] etc. to handle such a huge amount of data [XLIV].
Military Applications

Big data is used to improve military experiences, services and training. The main importance is given to real time command and control message authentication to provide security in cyber-physical systems [XLIV].

To secure the military communications efficiently, the authors in [I] developed a novel broadcast authentication scheme that uses a variety of digital signatures to generate and verify the signatures fast to bear the loss of packets in data transmission. The authors in [L] used the Markov decision process that proposes a method for military operations attacks recognition and reduction made easy and to protect the confidential information. Military satellite communication should be very strong as it has a high significance in succeeding the military missions. The assessment of protection based on matrices method is used to attain the significance which depends on the analysis of conventional risk that describes how the attack’s ease and impact are used in assessing the attacks [XXIII].

City Management

Big data facilities such as smart infrastructures and services are used for daily routine activities. By using smart cards, smart phones, and on-board vehicle sensors in either outdoor or indoor environment, the city can have a large amount of data that is used for detecting different dynamic patterns [XLVIII]. As an example, traffic patterns and routes are evaluated and then provide the guidelines to the humans to move faster and safer to their destinations.
The road sensors are proposed by authors of [XXXVI] to attain the particulars about the traffic like the movement of two wheelers, cars etc. in a particular location. After that, this information could be processed by using tools of big data and graph algorithms and decisions may be taken for smart and efficient transportation. Crowd detection system and traffic monitoring systems are the other safety systems for city management [XLVIII].

**Medical Applications**

The health systems of CPS are help in various medical sectors such as management of diabetes, blood pressure monitoring of heart rhythm, by providing in time, systematic and active medical decisions [XLVIII] [III]. The generation of large amount of data from the increase of health systems such as user applications, health monitoring systems etc. the data must be saved, monitored and maintained in order to observe the health condition of a patient in regular intervals [XLVIII].

**Disaster Events Applications**

Public safety networks should have flexibility and durability. The firefighters, law enforcement, medical persons and other stood as foremost respondents in the emergency or disaster event. The big data is used for supporting disaster events like evaluating high resolution maps’ large amount of data, drawing the scale diagrams for rooms, spaces, traffic patterns and transmission of outdoor videos to transform the messages to the organizations [XLVIII].

**IV. Elucidation of Big Data**

A large voluminous data that increases enormously is referred to as big data. Such large amount data is generated by different sources of various fields in different formats [X].

Big data is gathered from the user reviews and comments on products by several users, by sharing of the posts in social media, through questionnaires while purchasing in e-commerce sites etc. The sensors, other electronic chips and their programming help in gathering and storing the data at any time [X].

*Fig. 3: Smart City adopted from [XLVIII]*
Big data is stored in computer databases and this stored data is evaluated and decomposed into a specific format and large sets of data to retrieve it very easily whenever needed. The various tools are used to handle big data and some Software-As-A-Service (SAAS) companies provide services that manage big data [X].

Medical researchers and doctors recognize the severity of the disease and patient’s health condition by recording it in regular intervals by using Big data. Additionally, Big data provides the latest information about the spreading of infections, viral diseases etc., through electronic health records (EHRs), internet and other channels to Public Health Centre (PHC) [XII].

Big data helps in maintaining the energy and power stations to track the power grids. In power sub stations, the input and output current are to be recorded every minute to reduce the power fluctuations while transmitting the power for and industrial utilization [XII].

Big data systems are used in financial services firms to analyze the market information such as the increment and decrement of the share values and their risks. The product manufacturers, distributors and transport firms depend on big data to maintain their transactions of product supply, stock information etc. The recorded data related to their transactions help in maintaining continuous supply chain management among them. Big data is also helping in government departments in maintaining their workflow and to access the years ago data easily in all aspects respectively.

Big data is generated from unlimited several areas like online trading systems, health monitoring systems, mobile applications, customer databases, social media, research databases etc. The data is stored in the form of tables in the databases. Various database methods are used to extract the stored data then reprocess it so that it is ready for particular analytics uses [XII].

V. Tools and Techniques to Handle Big Data with Cyber Physical Systems

Now a days the data storage, analysis, predation and retrieving became more complicated because the data is in huge amount. In Cyber Physical Systems the large amount of data is stored and should be retrieved. So, we need many methods and approaches to maintain such data efficiently. Here in this section, we present various methods and approaches to maintain big data in different Cyber Physical Systems by reviewing several papers.

In [XL], the authors proposed and designed a tool for one of the applications of Cyber Physical Systems after referring the task scheduling problem. The performances of CPS are controlled by laws of feedback control. The authors co-designed the laws of control and schedule task algorithm for prediction and utilization of power for both the evaluating and the physical systems. They used the single processor controlled multiple inverted pendulums as an example to explain their technique. They developed both on the field and off the field algorithms to describe the multiple control task periods to balance the system power consumption under schedulable constraints.

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In [XLVII], the authors presented the taxonomy of CPS by defining the detailed summary of gather, save, retrieve, process and evaluation of the data. They also presented the various solutions to provide security, repository, retrieve and analysis of CPS big data. Additionally, they discussed how the CPS green challenges met by big data.

The impact of big data characteristics like volume, variety and velocity on data modelling and information systems design needs more research on them [III]. For this purpose, the conceptual modelling for big data exploration in a dynamic context of interconnected systems is used. The authors in [III] propose a model-driven approach that guides the design of multiple exploration strategies according to different objectives. They have given the description of the instantiation of the proposed concepts through some scenarios in the smart factory that helps in abstracting the implementation details and focusing on semantics of exploring data.

The virtualization status and the services based on cloud for system manufacturing and analytics of big data usage in providing different ways and control the operations in manufacturing are described in [XLIX]. The authors also explained about the processing of complex events, computing the cloud data and its virtuality, Internet of Things adoption, cyber security and big data analytics in the manufacturing area. Additionally, they also provide method for developing the model of Cyber Physical System with generated large amount of data and complex event processing to predict the operational overview.

In a research thesis [XVII], the authors presented their proposal of a logical and technological system architecture that provides to organizations the capability of using all their event data in the real time fashion. Next, they described some system architectures, the state-of-the-art that supports the identified problem, its research methodology, and then the result of their technical and logical system architecture.

The high speed, different patterned of huge data is maintained by a newly implemented method is described in [V]. The authors implemented correlation analytics and data mining stream to access significant information. To provide the real time data processing, the system uses Event processing engine as Esper to generate various events by using several language queries. They used topology Storm to grab and filter the real time stream of data. The Correlation and mining methods are handled by two different algorithms such as Apriori and FP-Growth algorithm.

VI. Conclusion

In this paper, a brief description of Cyber Physical System, its implementations in different areas such as military and medical applications etc., the increase of its growth and research scope is given. Also discussed the significance of storing and processing of big data in CPS along with the available various tools and techniques used for managing and processing voluminous data in several Cyber Physical Systems. As a result of this review, the ever-increasing demand of Cyber Physical Systems usage and the generation of large volume of data like moving from terabytes to zettabytes every day there always exist a future scope of research on
Cyber Physical Systems for developing more sophisticated intelligent algorithms to manage and process data in Cyber Physical Systems.

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