Cyber Physical System in the industry

N Kamaludin* and B Mulyanti
Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, 40 154 Bandung, West Java, Indonesia

*nurholis1987@gmail.com

Abstract. The Industrial Revolution 4.0 greatly affects the activity patterns of human life. Many sectors are feeling the impact of the industrial revolution 4.0, especially industry and education sectors. One of the technologies developed in the era of the Industrial Revolution 4.0, namely Cyber Physical System. This technology that integrates communications, control, and physically through the Internet. This paper was prepared aims to determine the model and the application of Cyber Physical Systems in the industry. The method used in the preparation of this paper, by reviewing the literature in journals that are in the range of 2014 - 2019. The search results and study, there are different models and ways of working are applied Cyber Physical Systems in industry. Based on these results of the study, it is hoped that alternative CPS models can be applied in the same field or developed in other relevant fields.

1. Introduction

Cyber Physical Systems (CPS) is a rapidly emerging field, which will touch every aspect of life in the near future, and life-changing about the way we interact with information and leads to the growth of information technologist [1]. Before three times the industrial revolution, mankind has experienced mechanization, electrification and information, now the industrial revolution the four had the biggest bright spot, making full use of the Internet, Internet of Things (IoT), a mobile communication network and other networks to enable the process of traditional industries become smarter and efficient, at the same time implementing the three functions consisting of reducing dependence on manufacturing employment, meet the individual needs of users, and reduce the cost of circulation [2]. CPS is an engineered system in which computing, communications technologies, and integrated tightly control [3]. CPS concept today can be considered as the main factors that contribute to the development of Industry 4.0 [4].

4.0 industrial concept introducing innovative technology in manufacturing that proposes new ways of connectivity and data management (Cloud Technology) and a new environment for sharing knowledge and training (Augmented and Virtual Reality) which became embedded in its production. This effort to reshape the form of current production machines and upgrade to CPS. Effect of increasing digitization in modern manufacturing, yielded promising results, more companies lined up to integrate technology into their system Industry 4.0 [5]. The idea of digitizing consistent and connect all productive units in the economy and create real-world virtualization into a very large information systems. Industry 4.0 must integration and assimilation of smaller concepts, such as "Cyber physical systems (CPS)", "Internet of Things (IoT)", "Internet of services (IoS)", "smart products" [3].
Figure 1. Frame-industry 4.0 and CPS [3].

The world is now starting the Fourth industrial revolution (Industry 4.0) where internet and information and communication technology (ICT) solutions are integrated into manufacturing equipment and making connectivity and communication that may have never been seen before [6]. With advances in sensor network technology, wireless communications, and other new technologies, more and more of the network, or smart objects, which are involved in the IoT. Meanwhile, this IoT related technology has also made a significant impact on information and communication technology (ICT) and the new CPS, thus paving the way for the realization of the Industry 4.0. Advances in radio-frequency identification (RFID), wireless sensor networks (WSN) and IOT are used to form a strong technology foundation to support CPS and also new emerging ICT. As a result, Industry 4.0 is able to develop a new generation of manufacturing systems that integrate and synchronize real-time data between physical objects and computing cyber space [7]. The development of these technologies, people still have a major role in decision-making and operations; the discussion is not about the unmanned factory but, on the contrary, man and machine working in collaboration. The level of complexity through the industrial revolution 4.0 is expected to grow even further and called for more skills among those who will operate the equipment complex [6].

This paper is intended to provide information related to the application of the CPS technology in the industry. The method used in this paper with a review of the literature, which is derived from the reference papers or journal published between the ranges of 2014 - 2019. This paper is organized into four parts, namely the first part about the introduction, the second part of the method, the third part of the results and discussion of the architecture and application of CPS technology in industry, and the fourth part of the conclusion.

2. Method
The method used in the preparation of this paper, is to conduct a literature review of some journals and papers proceedings which are in the range of 2014 - 2019. Search the journal or article can be from Google scholar, and Science Direct. There are 17 journals and 19 proceeding articles that discuss CPS related to different categories of discussion.
Table 1. List of journals and papers related to CPS published between 2014 – 2019.

| Year | Journals | Category | Proceedings | Category |
|------|----------|----------|-------------|----------|
| 2014 | 3        | Manufacturing, vehicle application, Concepts, Applications, and Challenges | 1 | Lifecycle Model |
| 2015 | 4        | Manufacturing, security and resilience, virtual engineering | 6 | Manufacturing, Inaugural issue, maintenance and service innovation, Real-Time Wireless, Virtual Engineering |
| 2016 | 2        | Manufacturing | 3 | Forensic, learning factories, production environments |
| 2017 | 3        | Security, production systems, components | 4 | Vocational training, manufacturing, predictive production systems |
| 2018 | 3        | Smart Cities development, Security, Industry 4.0 | 5 | Teaching Factory, Manufacturing, Industrial Engineering, Key Performance Indicators, Security |
| 2019 | 2        | Science of design for societal, Improved control | - | - |
| Total | 17 | - | 19 | - |

3. Results and discussion
The development of advanced communications technologies, has an impact on the manufacturing technology, one application of CPS in the manufacturing industry. Figure 2 below shows the concept map for implementing CPS in various fields:

![Figure 2. Concept map CPS [6].](image-url)
Based on Figure 2 marked box indicates that the CPS can be applied in various fields, namely: communication, customer, energy, infrastructure, healthcare, manufacturing, military, robotics, and transportations. Systematically introduce CPS origin, association with other research fields, and practical applications in various fields [8]. Based on literature review of several journals related to the implementation of CPS in the industry, there are some points that can be discussed as a result of the literature review are as follows:

### 3.1. Benefits of CPS

Application of CPS in the industry have benefits such as the following: **First**, the equipment used can be monitored continuously, so that the status or condition of the equipment can be seen clearly. **Second**, it can control the function of each equipment through the remote. **Third**, it can work automatically, based on the sensor data and industry-specific algorithms. **Fourth**, the field into real service activities, such as maintenance and repair predictive and preventive, to minimize downtime occurs in the manufacturing process, thereby increasing customer satisfaction. **Fifth**, can diagnose the fault and the damage from a distance.

The benefits of implementing CPS above, are inseparable from the involvement of physical factors, information technology, and control. CPS is an engineered system in which computing, communications technologies, and integrated tightly control [3]. The benefits of implementing the CPS can be applied to the industrial service sector [9].

### 3.2. CPS architecture

Based on the major components involved, CPS 3C having an architecture that is: 1) Human Component (HC), 2) Cyber Component (CC), and 3) Physical Component (PC). In addition, the HC-CC interface, CC-PC, and HC-PC plays an important role in connecting all the components into an integrated system to achieve a common goal. Explanation of the relationship between the three components can be seen in figure 3 below. Clever product is a physical product that is equipped with embedded systems, sensors, and actuators [10].

![Architecture CPS 3C for industry 4.0](image)

**Figure 3.** Architecture CPS 3C for industry 4.0 [10].

Based on the picture above, that the CPS has three main components: physical components (mechanical parts and the case of electric / electronic), intelligent components (control systems, sensors, microprocessors, data storage, software, and user interface) and component connectivity (port, an antenna, and a wired or wireless interface protocol). The three components are interconnected and have an important role. In the production of cyber-physical systems, in which the human factor will do so
increasingly play an important role, there is a clear need to consider man as an endogenous interaction component in the CPS [10].

Based on the principle works on a system of manufacturing industry, architecture CPS has 5 levels are as follows: 1. Connection, 2. Conversion, 3. Cyber, 4. Cognition, 5. Configuration. This architecture is called 5C level.

![Architecture 5C for the implementation of Cyber-Physical Systems](image)

**Figure 4.** Architecture 5C for the implementation of Cyber-Physical Systems [11].

![Applications and techniques associated with each level of the architecture 5C](image)

**Figure 5.** Applications and techniques associated with each level of the architecture 5C [11].

Figure 4 and 5 show phases or work steps of CPS applied in the manufacturing industry. The first step **Connection**, in this step is to obtain accurate and reliable data. Such data may include voltage, current, temperature, vibration, rotational speed, speed feeds, and the concentration of engine oil and components, as well as images and videos of the work piece. The data is the result of direct measurements by sensors or obtained from the controller in the form of Program Logic Control (PLC) or manufacturing systems such as management or production systems (ERP, MES) [12]. Two important factors at this level should be considered. First, consider the various types of data, and the use of effective methods. The second factor is choosing the right sensor (types and specifications).

The two step conversion, Data obtained is then converted into an information. Several mechanisms can be used to realize the data conversion information. The mechanism developed for prognostic and health management engine. This level of self-awareness to bring the property into the machine. The third step cyber, the step is to act as an information center in this architecture. Information pushed to it
from any machine connected to form a network of machines. Having a large information gathered, a
special analysis should be used to extract additional information provides better insight about the status
of each - each machine in the fleet. This analytic capabilities provide the machine with its own
comparison, where the performance of the engine can be compared to and judged among the fleet. On
the other hand, similarity between the performance of the engine and assets prior (historical information)
can be measured to predict the behavior of the engine in the future. At this level, the presentation of the
appropriate analytical information is provided to the user to make a decision. Priority tasks for the
maintenance process can be easily determined because the availability of comparative information and
status of individual machines [13].

The fourth step cognition, at this level resulted in a thorough knowledge of the system being
monitored. The knowledge gained in support of expert users to make the right decision. The fifth step
configuration, the feedback from cyber space to physical space and act as a watchdog to make engine
control configures itself and adapt. This phase acts as a resistance control system (RCS) for
implementing corrective and preventive decisions that have been made in cognition level, to the system
being monitored.

3.3. Virtual engineering

Virtual Simulation Object Engineering (VEO) / Virtual Engineering Process (VEP) is one of the key
aspects to achieving CPS for Industry 4.0. VEO is a living representation of the object that is capable of
capturing, adding, storing, enhancing, sharing, and reusing knowledge through experience, in a manner
similar to an expert in that object. VEO can summarize the knowledge and experience of each of the
important features associated with engineering objects [3], This can be achieved by collecting
information from six different aspects of an object: the characteristics, functions, requirements,
connections, current status, and experience [14].

Virtual engineering process (VEP) is a knowledge representation of the process of making / planning
process artefact has all the information about the store level operations necessary; sequence and
resources needed to produce it as shown in the figure below. VEP associated with choosing the required
manufacturing operations and the determination of their order, as well as the selection of manufacturing
resources to "transform" the design model into a physical component that is economic and competitive
[3].

Figure 6. Correlation between the physical and virtual world [3].

Figure 6 shows that in a manufacturing environment, the collection component / tool / object is a process
and a combination of a system that can be represented virtually in the form of VEO. There are three
features: (i) the insertion of the decision model is expressed by a set of experiences, (ii) the geometric
representation, and (iii) the means necessary to connect virtualization with physical objects represented.
While VEP associated with choosing the required manufacturing operations and the determination of
the order, as well as the selection of manufacturing resources to 'transform' the design model into a physical component and a competitive economy [15].

The planning process is a combination of the required information on its operations, the order of manufacture, and machinery required. In addition, for VEP, VEO of information all the resources associated with the process is also required. Therefore, to summarize the knowledge of the areas mentioned above, designed VEP has three main elements or modules as in figure 7 below:

![Figure 7. Architecture VEP [3].](image)

**First Operation**, these are sub categories and have interaction planning functions which include [3]: a). Scheduling routes - based on global and local geometries, b). process - process capability and process costs, and c). Process parameters - tolerance, surface finish, size, type of material, quantity, and urgency. **The second source**, based on past experience information about the resources used to produce the components mentioned in the VEP operating module is stored here. Knowledge of the level of the machine stored in this case is as follows [3]: a). election machinery and equipment - machine availability, the ability of the machine cost, size, length, cut length, stem length, space, materials, geometry, coarsening and finishing, and b). election fixture - fixture elements function, seek, support, clamping surfaces, stability. **The third experience**, in the experience module, links to the SOEKS of VEO’s along with VEP having past formal decisions to manufacture engineering components are stored. They represent the links to SOE’s based on past experience on that particular machine to perform given operation along with operational and routing parameter.

**4. Conclusion**

Based on a review of literature, that in the era of industrial revolution 4.0, the application of the CPS has become a trend in the industry. It is beneficial to simplify the process of planning, production and maintenance of the system that are in the industry. In addition, the implementation of CPS can be utilized in the business services industry to monitor, control, operation automatically, and diagnose equipment failure remotely. One achievement of the industrial application of CPS 4.0 can be simulated through virtual technology in the industry, namely Virtual Object Engineering (VEO) / Virtual Engineering Process (VEP). In the manufacturing industry VEO objects related technique has three features, namely: 1). Set experience, 2) the geometric, and 3). Means. While VEP election-related manufacturing operations. As for the implementation of CPS in the industry has an architecture 3C and 5C. 3C architecture there are three components: 1) the human component (HC), 2) a cyber-component (CC), and 3) physical component (PC). Architectural while 5C: 1. Connection, 2. Conversion, 3. Cyber, 4. Cognition, and 5. Configuration. Research and application of CPS will continue in the coming years, not only for the unsolved problems, but also for complex and interesting as well as challenging the researchers next.
References

[1] Mahmoud M S and Hamdan M M 2019 Improved control of cyber-physical systems subject to cyber and physical attacks Cyber-Physical Syst 5(3) 173–90

[2] Zhou K, Liu T and Liang L 2016 From cyber-physical systems to Industry 4.0: make future manufacturing become possible International Journal of Manufacturing Research 11(2) 167–88

[3] Shafiq S I, Sanin C, Szczerbicki E and Toro C 2015 Virtual engineering object/virtual engineering process: A specialized form of cyber physical system for industry 4.0 Procedia Comput Sci 60(1) 1146–55

[4] Navickas V, Kuznetsova S and Gruzauskas V 2017 Cyber–physical systems expression in industry 4.0 context Фінансово-кредитна діяльність: проблеми теорії та практики (2) 188-197

[5] Mourtzis D, Vlachou E, Dimitrakopoulos G and Zogopoulos V 2018 Cyber-Physical Systems and Education 4.0 -The Teaching Factory 4.0 Concept Procedia Manuf 23(2017) 129–34

[6] Wang L, Törmgren M and Onori M 2015 Current status and advancement of cyber-physical systems in manufacturing J Manuf Syst 37 517–27

[7] Xu L D, Xu E L and Li L 2018 Industry 4.0: State of the art and future trends Int J Prod Res. 56(8) 2941–62

[8] Gunes V, Peter S, Givargis T and Vahid F 2014 A survey on concepts, applications, and challenges in cyber-physical systems KSII Trans Internet Inf Syst. 8(12) 4242–68

[9] Herterich M M, Uebernickel F and Brenner W 2015 The impact of cyber-physical systems on industrial services in manufacturing Procedia CIRP 30 323–8

[10] Ahmadi A, Sodhro A H, Cherifi C, Cheutet V and Ouzrout Y 2018 Evolution of 3C cyber-physical systems architecture for industry 4.0 International Workshop on Service Orientation in Holonic and Multi-Agent Manufacturing pp 448-459

[11] Lee J, Bagheri B and Kao H A 2015 A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems Manuf Lett 3 18–23

[12] Juhás P and Molnár K 2017 Key components of the architecture of cyber-physical manufacturing systems Industry 4.0 2(5) 205-207

[13] Ahmadi A, Cherifi C, Cheutet V and Ouzrout Y 2017 A review of CPS 5 components architecture for manufacturing based on standards 2017 11th International Conference on Software, Knowledge, Information Management and Applications (SKIMA) pp 1-6

[14] Shafiq S I, Sanin C, Toro C and Szczerbicki E 2015 Virtual engineering object (VEO): Toward experience-based design and manufacturing for industry 4.0 Cybern Syst. 46 35–50

[15] Shafiq S I, Sanin C, Toro C and Szczerbicki E 2016 Virtual engineering process (VEP): a knowledge representation approach for building bio-inspired distributed manufacturing DNA Int J Prod Res. 54(23) 7129–42