Development of Cyber-Physical System (CPS) implementation in industry 4.0

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Abstract. The purpose of this study is to analyze the concept of a cyber-physical system (CPS). The current industry applied it. The method used in making this paper is a systematic literature review. From the results of the literature study, the author founded that CPS is a management model in industry 4.0 that applies the principle of integration of cyber-physical and cyber humans. Cyber human systems (CHS) can provide information feedback at every level because social workers have inherent intelligence, which can be exploited naturally for self-adaptation, corrective, and preventive actions. The CHS configuration level serves as a supervisory control so that decisions made at the level of cognition can be applied, and human workers follow corrective and adaptive measures. As an implication, the role of humans is still vital in industry 4.0.

1. Introduction
The era of digital manufacturing occurred in the mid-20th century, triggered by the development of information technology and full applications, including computers, communication, and numerical control [1,2]. From the perspective of a system composition, intelligent manufacturing systems are always in the form of Human-cyber-physical systems (HCPS) - that is, a kind of integration of intelligence systems consisting of humans, cyberspace systems, and physical systems [3]. Smart manufacturing is a general concept that already exists and continues to evolve with the development and integration of information technology and manufacturing technology. In general, smart manufacturing has gone through the stages of digital fabrication and digital network manufacturing. It continues to grow towards new-generation intelligent building (NGIM), as a result of the rapid development and breakthroughs that have occurred on the internet, Big data, and artificial intelligence (AI) [4-8].

With increasingly sophisticated technology that allows smaller dimensions of the device [9]. Based on these capabilities, the device can be paired with other components such as wireless communication technology, sensors, and other supporting elements to determine the state of the environment; then, the actuator can respond. Combining the digital world with the physical world is a discourse that arises from this. Cyber-physical (CPS) has been defined as a system where physical space is integrated with computing, communication and control systems (cyberspace) [10,11].
To renew the manufacturing industry, Indonesia is committed to accelerating the implementation of the Industrial Revolution 4.0. Through Making Indonesia 4.0, Indonesia is committed to increasing the research costs of developing a variety of advanced technologies, such as artificial intelligence (AI), Internet of Things (IoT), wearables, sophisticated robotics, and 3D printing. This also leads to the application of the Cyber-Physical system. Indonesia will focus on five main sectors for the initial adoption of this technology, namely (i) food and beverages, (ii) textiles and clothing, (iii) automotive, (iv) chemistry, and (v) electronics [12].

Cyber-physical system (CPS) as one aspect in the cyber-system of the industrial revolution 4.0 is currently widely used by industry for its development. The cyber-physical system is one aspect of the cyber-system of the industrial revolution of 4.0. This system makes it possible to connect physical devices with the internet network. Even this system also allows for control and response from the internet to physical shaped machines through actuators and sensors [13]. Industry Concept 4.0 introduces innovative technology in manufacturing that uses new ways regarding connectivity and data management (Cloud Technology) and unique environments for sharing knowledge and training (Augmented and Virtual reality) that are integrated into the system. This leads to the latest production machines and increases to the Cyber-Physical Systems [14]. In anticipation of a shortage of well-trained personnel at all levels of manufacturing who can handle the knowledge requirements of an ever-changing sector that integrates technological breakthroughs, it is essential to reshape methods of manufacturing education, linking industry with technical education. The purpose of this study is to analyze the concept of a cyber-physical system (CPS). The current industry applied it.

2. Method
The method used in this article is the systematic literature review. The author chose the practice because it can identify, evaluate, and interpret research data and results by predetermined research questions [15]. Also, a systematic literature review can be used to minimize bias, distribute literature search frameworks, and make it possible to conduct comprehensive analyzes, and Systematic literature review is intended to explore the extent of the development of the current Cyber-physical system, to analyze the CPS concept applied in the current industry.

Systematic Literature Review consists of three stages: searching and filtering literature, analyzing literature, and writing the results of the analysis in the form of scientific arguments. Literacy sources come from several online sources. Some library databases used are Google Scholar, Scopus, and Thomson. The publishers used were Sciencedirect, Springer, Taylor and Francis, IOP, DOAJ, and Nature. Keywords used for literature search are the Cyber-Physical System, Industry 4.0, Teaching Factory, curriculum alignment, curriculum relevance, relationships and compatibility, industrial relations industry, industrial school collaboration, vocational schools, vocational schools, and professional school determinations. In addition to keywords, there are specific criteria for filtering literature searches, including articles published in the last five years (2015-2019), journals, and research articles. Each item was evaluated by the researcher for the three main focuses of the discussion are the Cyber-physical system, Industry 4.0, and the content of the information presented.

3. Results and discussion
CPS is defined differently by scientists based on their scientific perspectives. CPS is an integration of various fields of science and engineering, namely professional computer and network scientists to collaborate closely with experts in areas such as automation and control, civil engineering, mechanics and biology [3].

Cyber Human System (CHS) can provide information feedback at every level because human workers have inherent intelligence, which can be exploited naturally for self-adaptation, corrective, and preventive
actions. The CHS configuration level serves as a monitoring control so that decisions made at the level of cognition can be applied, and human workers follow corrective and adaptive actions [4]. The 5-level CPS structure, the 5C design, provides step-by-step guidance for developing and deploying CPS for manufacturing applications. In general, CPS consists of two main functional components: (1) sophisticated connectivity that ensures real-time data acquisition from the physical world and information feedback from cyberspace; and (2) intelligent data management, analytics and computing capabilities that build cyberspace [5].

Analysis of the performance of fog and cloud cyber-physical interfaces illustrates some of the strengths and weaknesses of both approaches. In particular, industrial engineering applications dependent on raw computing performance (eg, implementing complex machine learning models) can benefit from interfacing with the cloud. In contrast, those applications demand consistent and reliable real-time execution (eg, minimizing failed communication) can choose to interface using the haze paradigm. Of course, many engineering applications require a mixture of both computing latency and consistency to meet requirements, which might be overcome by changing the underlying CPS hardware and software architecture [6]. From the results of the literature study, several articles relating to CPS were found as shown in Table 1.

Table 1. Summary of articles about Cyber-Physical Systems.

| No | Title                                                                 | Context                                                                 | Method                                    | Participants | Finding Basic                                                                 | Relations with the research topic |
|----|----------------------------------------------------------------------|------------------------------------------------------------------------|-------------------------------------------|--------------|--------------------------------------------------------------------------------|------------------------------------|
| 1  | Olivier cardin, (2018). Classification of Cyber-Physical Production Systems Applications: Proposition of analysis framework [16] | Analytical framework for classifying the development of cyber-physical Production Systems | Extensive Study of literature             |              | Introducing a new analytical framework for classifying Cyber-Physical Systems | Development of Cyber-Physical System in Industry |
| 2  | Matthew Krugh , Laine Mears, (2018). A complementary Cyber-Human Systems framework for Industry 4.0 Cyber-Physical Systems. [17] | Framework for renewal focus on the use of human labor in industry 4.0 | Extensive Study of literature             |              | Humans still continue to play an important role in the future automotive factory environment | The role of humans in the development of Cyber-Physical Systems |
| 3  | Peter O'Donovan, et al, (2019). A comparison of fog and cloud computing cyber-physical interfaces for Industry 4.0 real-time embedded machine learning engineering applications [18] | Comparing latency performance and reliability of cyber-physical interfaces implemented with the traditional cloud computing and emerging fog computing paradigms, to bring real-time embedded machine learning engineering applications to Industry 4.0 | Experiment Method                         |              | Compare latency and consistency of cloud and fog interfaces that connect the factory operations to machine learning models in the cyber world | Illustrating how some of these measurements align or conflict with Industry 4.0 design principles |
| Table 1. Cont,                                                                 |                                                                 |                                                                 |                                                                 |
|--------------------------------------------------------------------------------|------------------------------------------------------------------|------------------------------------------------------------------|------------------------------------------------------------------|
| **4.** D. Mourtzis, E. Vlachou, G. Dimitrakopoulos, and V. Zogopoulos, “Cyber-  | Industry 4.0 based Teaching Factory Learning                      | Prospective engineers can be trained in Industry 4.0 in collaboration with experts | Teaching factory learning in Industry 4.0                         |
| Physical Systems and Education 4.0 - The Teaching Factory 4.0 Concept,” in Proc  |                                                                 |                                                                 |                                                                 |
| edia Manufacturing, 2018 [19]                                                |                                                                 |                                                                 |                                                                 |
| **5.** Y. Liu, Y. Peng, B. Wang, S. Yao, and Z. Liu, “Review on cyber-physical  | Introducing CPS concepts and characteristics and analyzing the current CPS research situation | The concept and characteristics of CPS and analyze the current CPS research situation. Then the development of CPS is discussed from the perspective of system models, information processing technology and software design, the main barriers and the main research and developing CPS | The development of CPS in the industrial world                     |
| systems,” IEEE/CAA J. Autom. Sin., vol. 4, no. 1, pp. 27–40, 2017 [20]        |                                                                 |                                                                 |                                                                 |
| **6.** B. Bagheri, S. Yang, H. A. Kao, and J. Lee, “Cyber-physical systems   | CPS implementation guidelines Literature Study                   | 5C design as a guideline for CPS implementation                   | CPS Implementation Guidelines                                     |
| architecture for self-aware machines in industry 4.0 environment,” in IFAC-  |                                                                 |                                                                 |                                                                 |
| PapersOnLine, 2015 [10]                                                      |                                                                 |                                                                 |                                                                 |
| **7.** Zhou Ji a, Zhou Yanhong b,†, Wang Baicun c,d,†, Zang Jiyuan. Human-Cyber- | Evolution of HCPSs for intelligent manufacturing Literature study | Development of the Human Cyber-Physical System                   | The superiority of human intelligence is still needed in future industries |
| Physical Systems (HCPSs) in the Context of New-Generation Intelligent         |                                                                 |                                                                 |                                                                 |
| Manufacturing                                                                 |                                                                 |                                                                 |                                                                 |
From a summary of articles about the Cyber-Physical system, the authors conclude that the role of humans is still significant in the future industry, the division of labor and practical cooperation between humans and intelligent machines can grow simultaneously.

The human element must be integrated into the CPS Industry 4.0 design. The human element is considered challenging to develop in cyberspace is a common and natural thing. Need to prepare human resources that are adaptive to the future development of the industry, especially at the secondary school level.

CPS consists of two main functional components: (1) sophisticated connectivity that ensures real-time data acquisition from the physical world and feedback information from cyberspace; and (2) intelligent data management, analytics and computing capabilities that build cyberspace. However, such requirements are very abstract and not specific enough for general implementation purposes.

The structure of the 5C CPS, namely the 5C design [10], provides step-by-step guidance for developing and deploying CPS for manufacturing applications. 5C design through sequential workflow, how to make CPS from initial data acquisition to analysis, to creating final value. As illustrated in Figure. 1, 5C architecture is described in detail as follows:

![5C architecture](image)

**Figure 1.** 5C architecture for implementation of Cyber-Physical System.

1) Smart Connections
   The first step in developing a Cyber-Physical System Application is to obtain accurate and reliable data from the engine and its components.

2) Data-to-information conversion
   Meaningful information must be deduced from the data. At present, there are several tools and methodologies available for data to information conversion rates.

3) Cyber
   The practical level acts as a center of information in this design. Information is driven from each machine that is connected to form a network of machines.

4) Cognition
   Applying CPS at this level results in a thorough knowledge of the system being monitored. The right presentation of experience obtained for expert users supports correct decision making. Because comparative information, as well as individual machine statuses, are available, decisions...
on priority tasks to optimize maintenance processes can be made. For this level, an appropriate info graph is needed to transfer the knowledge obtained to the user entirely.

5) Configuration

Configuration level is feedback from cyberspace to physical space and acts as a supervisory control for self-configuring and self-adjusting machines. This stage acts as a resilience control system (RCS) to apply corrective and preventive decisions, which have been made at the level of cognition, to the order being monitored.

4. Conclusion

The working principle of the CPS-based industry is to implement the integration of cyber-physical and cyber humans. Cyber human systems (CHS) can provide information at every level because social workers have inherent intelligence, which can be exploited naturally for self-adaptation, corrective, and preventive action. The CHS configuration level serves as a supervisory control so that decisions made at the level of cognition can be applied, and human workers follow corrective and adaptive actions. Therefore, the role of humans is still critical in industry 4.0.

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