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Enhancing Inventory Accuracy through Stock-Taking in Production Monitoring Systems for Workstations

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Abstract

Industry 4.0 promotes the use of Cyber-Physical Systems (CPS) to improve production efficiency through seamless data exchange between virtual and physical components. However, in manual labor-driven environments, discrepancies between virtual stock data and actual material usage can create challenges for accurate production monitoring. This study focuses on addressing these discrepancies by integrating a stock-taking method into a production monitoring system. The system was implemented in an air conditioning train car assembly workshop, where differences of 2–3% between the predicted virtual stock and real-world quantities were identified. By applying the stock-taking method, virtual data were recalibrated to reflect real-time stock levels more accurately. The system's ability to track material usage and losses allowed for significant improvements in inventory accuracy, with immediate updates provided to the CPS. This approach minimizes human error in manual operations, ensuring that material predictions are more aligned with actual consumption. The results show that the implementation of the stock-taking method reduced the margin of error in stock predictions, improving overall production decision-making. These findings suggest that this method can enhance stock accuracy in manufacturing sectors, particularly in developing countries where manual labor is predominant. This study provides practical implications for optimizing material management and reducing production costs by leveraging CPS integration with stock-taking methods.

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1. Introduction

The evolution of technology has become one of the primary drivers of increased productivity in the industry, with improvements ranging from 44% to 55% [1]. Industry 4.0 is a key concept that can be applied to enhance productivity in manufacturing [2]. Generally, the implementation of Industry 4.0 in the manufacturing sector involves the development of intelligent production systems capable of exchanging valuable information, enabling production elements to make control decisions autonomously [3]. A critical component of Industry 4.0 is the Cyber-Physical System (CPS) [4]. In CPS, each real-world production element is represented by a corresponding virtual model. These virtual models can communicate with other elements within the virtual environment, providing essential support for decision-making processes that address production management challenges.

CPS is already widely used in research. For instance, [5] utilized a CPS representation for production scheduling and validating schedules across entire production systems. A method for automated task scheduling, evaluated in automotive kitting applications, is proposed in [6], which aims to integrate robots into production processes both vertically and cyber-physically. The deployment of CPS for diverse multi-robot fleets engaged in remote inspection missions is discussed in [7]. Additionally, [8] explores how a robot plans a feasible path in a virtual simulation environment with the assistance of CPS.

However, many manufacturing industries in developing countries are still reliant on manual labor, limiting the extent to which full CPS automation can be applied. The existing CPS frameworks tend to be cost-prohibitive and socially unfeasible for labor-intensive industries, particularly when it comes to real-time monitoring and accurate tracking of material usage. These industries often

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experience significant discrepancies between virtual stock data generated by CPS and actual material consumption due to human error, variability in manual processes, and non-standardized operations. Current systems designed for highly automated environments do not effectively address these discrepancies in semi-automated or labor-intensive settings.

Modification of the Industry 4.0 concept to suit the operational conditions of factories is necessary, especially for manufacturing industries still in the Second Industrial Revolution phase. In such industries, implementing full automation with robots is often too costly, both in terms of investment and social implications. A Configurable Virtual Workstation (CVWS) concept was developed [9], [10] as a modification of the Industry 4.0 framework, allowing it to be applied by manufacturing industries in developing countries. This system can capture data on operational activities, operators, and materials at the workstation. Management can derive various types of information from the processed data [11], including material stock levels at the workstation. However, a slight discrepancy exists between the virtual stock data and the actual data at the workstation due to the inconsistent use of consumable materials by operators during product assembly. Operators may use consumable materials, such as cables, in quantities less than or greater than those specified by the Standard Operating Procedure (SOP), as seen in the example from the railway carriage HVAC industry, shown in Table 1. This results in the virtual warehouse data not matching the real warehouse stock data.

Table 1. Difference between SOP quantity and Real quantity for consumable materials

Item	SOP Qnt (meter)	Real Qnt (meter)
Harness wire	5	5-5.1
Soft vinyl	5	5-5.1
HLPS wire	10	10-10.1
Soft vinyl	10	10-10.1
Fan evap wire	15	10-10.1
Soft vinyl	15	10-10.1

To resolve the issue, the virtual model data will be calibrated with the workstation data using the stock-taking method. This paper describes the implementation of the stock-taking method in the existing production monitoring system to identify the cause of discrepancies between virtual and workstation data. The study aims to address this gap by integrating the stock-taking method into a CPS-based production monitoring system. By periodically calibrating virtual stock data with real-time physical measurements, the system can more accurately reflect the actual consumption of materials during production. The stock-taking method allows for adjustments based on manual operations, which are inherently more variable than machine-based processes. This approach provides a cost-effective and scalable solution for labor-intensive industries, enabling them to adopt CPS technologies without requiring full automation. The proposed solution reduces discrepancies between virtual and real data, ensuring improved inventory management, minimizing material waste, and enhancing decision-making capabilities in production management.

2. Methods

A critical component of the Industry 4.0 concept is the Cyber-Physical System (CPS). The main purpose of CPS is to link real production elements with their virtual counterparts, as shown in Figure 1 [12]. CPS also provides resources that enable the physical integration of these elements with the virtual world, where embedded systems monitor production elements connected to the network and control physical processes, which in turn influence information processes. CPS considers physical resources and network processes to facilitate the merging of physical and virtual objects [13].

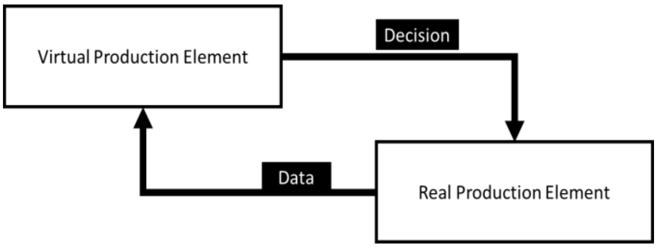


Figure 1. Cyber-physical system

In other words, every real production element must have a virtual model as its representative. This virtual model can communicate with other objects in the virtual environment to support the decision-making process in resolving production management issues. Changes in real-world data must be transferred to the corresponding virtual models in the CPS for proper functionality. Using this data, the virtual model can make decisions to control production. Through the integration and collaboration of computing, communication, and control—known as the "3C" framework—CPS provides real-time sensing, information feedback, dynamic control, and other essential services [14].

Another concept used in the system is the Configurable Virtual Workstation (CVWS). The workstation concept serves to bridge real production elements with virtual elements. A workstation is a designated area where specific tasks are performed, and it monitors every production element within its scope. Any changes in the conditions of these elements are recorded, and data is updated by the workstation. These changes occur due to events such as the start or end of production activities, the entry and exit of operators, products, or tools, and other related activities.

A general description of the workstation model is shown in Figure 2. The production elements being modeled include materials, components/products, and operators. There is no machine tools located at the workstation. For the virtual model to detect the presence of real-world elements, these elements are assigned identifiers. For example, operators are tagged with RFID and given an account to enter the application, while materials, components, and products at the workstation are identified using barcodes.

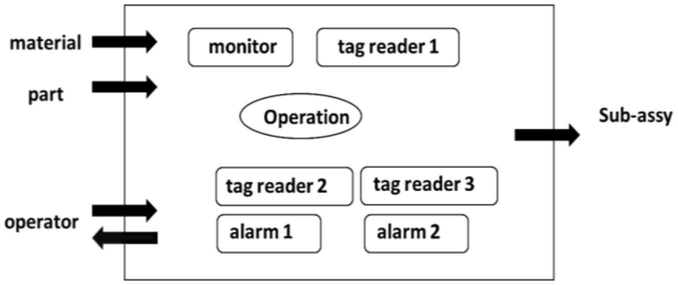


Figure 2. Workstation model

References [15] ,[16], and [17] discuss the use of CPS in warehouse management, but they do not address its integration with CPS in production activities. The proposed solution aims to combine warehouse management and production activities into a unified CPS by modifying the CVWS concept. The data for all materials entering the shop floor will be stored in a database. Each material is assigned an ID, and the material ID stores information about the quantity and type of material. Barcodes containing the material ID data will be placed on each material. When a material is used in an operation, the system automatically reduces the quantity based on the product model. To calibrate the material quantities between the real world and the virtual world, a stock-taking activity will be conducted to monitor the remaining material in specific workstations at the end of the day. The stock-taking data will be used for the next operation in the workstation.

3. Results and Discussion

The data flow scheme for stock-taking recording in production monitoring systems is shown in Figure 3. Material quantity data must be entered by the operator into a smartphone to record every event change that occurs. The smartphone then transmits the data to a web server on a computer via a wireless network. The web server processes the data sent from the smartphone and stores it in a database using PHP programming. When the smartphone sends requests to the web server through the wireless network, the server processes the request and retrieves the requested data from the database, sending it back to the smartphone via the same network. The web server used is Apache, which is part of the XAMPP software package. XAMPP was selected because it offers a complete package, including a web server, PHP programming language, and MariaDB database, all in one software solution.

The app interface is shown in Figure 4. To perform the stock-taking activity, the warehouse staff first presses the "Opname" button. The application then directs them to a page where they can scan the barcode of the material to be recorded.

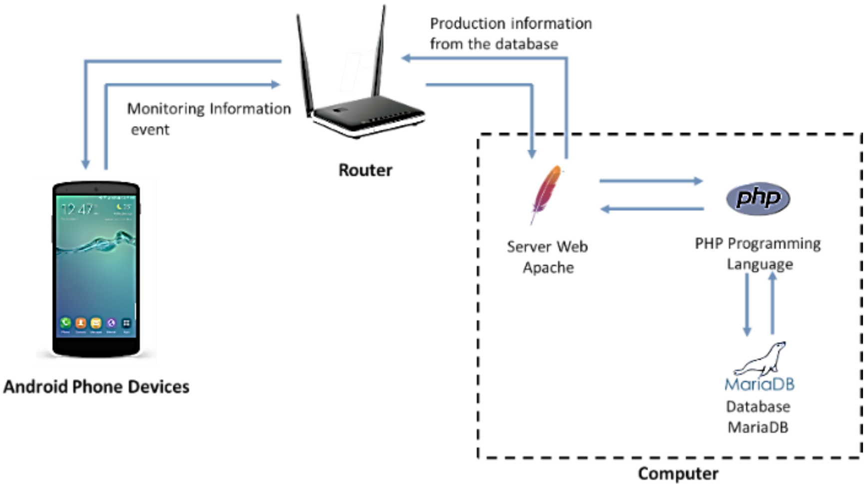
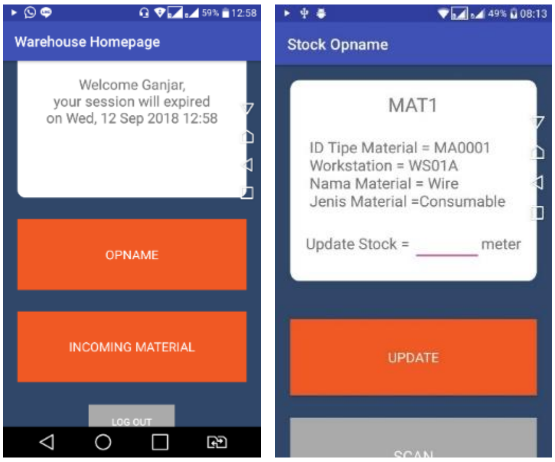


Figure 3. Data flow scheme



Welcome Ganjar,
your session will expired
on Wed, 12 Sep 2018 12:58

ID Tipe Material = MA0001
Workstation = WS01A
Nama Material = Wire
Jenis Material =Consumable

Update Stock = ______ meter

Figure 4. App interface

Table 2. Stock quantity from system and actual

Node	Parent Node	Node Name	Qnt System (meter)	Qnt Real (meter)
MAW0100	\N	Wire harness	\N	
MAW0101	MAW0100	Harness wire	95	93
MAW0102	MAW0100	Soft vinyl	50	49
MAW0103	MAW0100	Skun	\N	
MAW0104	MAW0100	Females insert	\N	
MAW0105	MAW0100	House female	\N	
MAW0200	\N	HLPS assy	\N	
MAW0201	MAW0200	HLPS wire	110	108
MAW0202	MAW0200	Soft vinyl	80	78
MAW0203	MAW0200	HLPS	\N	
MAW0204	MAW0200	Skun	\N	
MAW0300	\N	Fan evap assy	\N	
MAW0301	MAW0300	Fan evap wire	105	102
MAW0302	MAW0300	Soft vinyl	65	63
MAW0303	MAW0300	Fan evaporator	\N	
MAW0304	MAW0300	Skun	\N	

The flow of the stock-taking process is illustrated in Figure 5. The warehouse staff scans the material's barcode, and information about the material appears, along with a form to enter the remaining quantity. The staff then inputs the remaining material quantity and presses the "update" button, which sends the data to the database. If the entered data is larger than the previous material quantity recorded in the database, the data will be rejected, as it is not possible for the quantity in the warehouse to exceed the system's predicted amount; otherwise, this would indicate a violation of the SOP by the operator. If the data is valid, it will override the existing material quantity data in the database. Finally, the system will use the new data from the stock-taking activity to predict the material needs for the next day's production activity in the CPS.

Table 2 shows the product structure data used to simulate operations in the monitoring system. The final product is represented by data without a parent node, and each final product consists of several components. Testing is performed by comparing the predicted material stock data from the CPS with the stock-taking data from experiments. The stock quantities from the system and the experiments are listed.

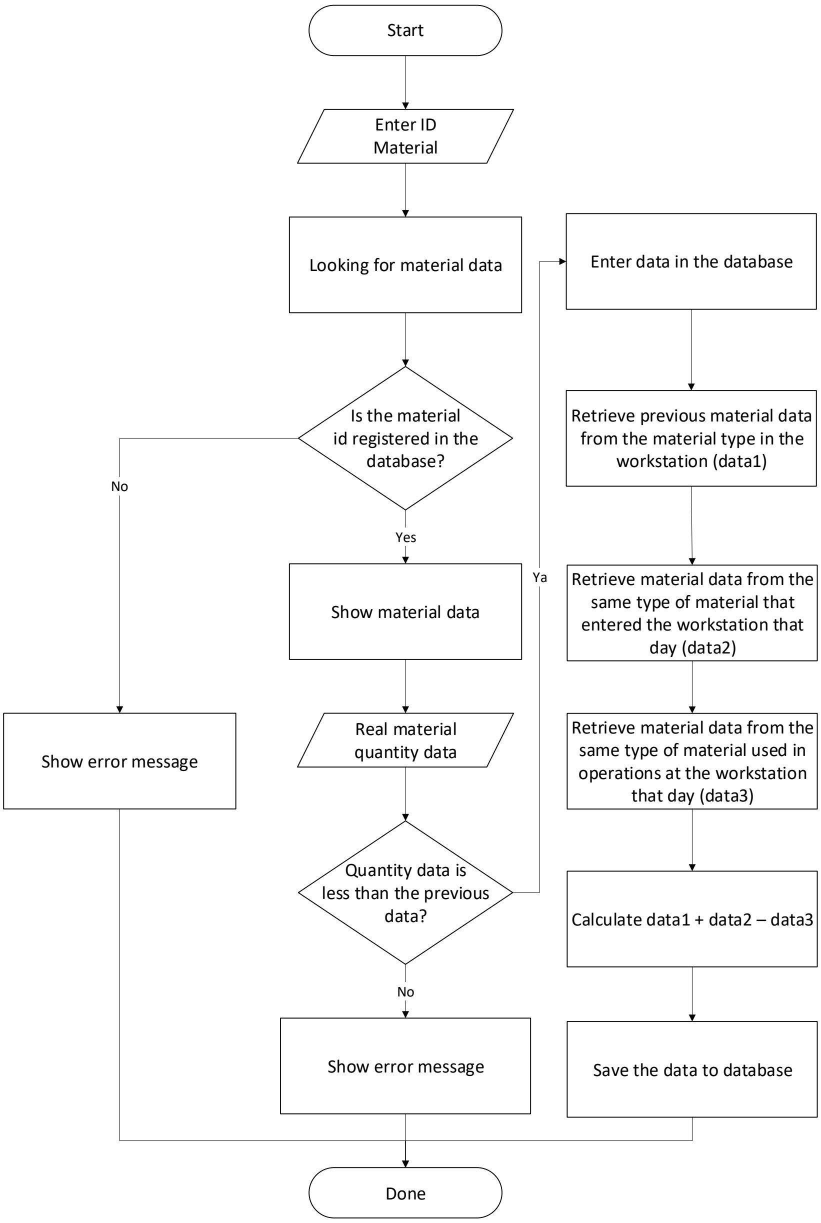


Figure 5. App flowchart

Based on observations, the system has successfully recorded a reduction in material data. However, when compared with stock-taking data, there is a 2 to 3 percent discrepancy between the two. This could occur due to uncontrollable factors, such as differences in how operators handle tasks during production. Unlike machines, operators may not always cut cables accurately, resulting in varying lengths that do not always match the lengths specified in the procedure. Despite having standard operating procedures (SOP) on the shop floor, human error is likely, especially in environments where manual labor is involved. As a result, there will always be some differences between the virtual data and the actual data. When this occurs, the CPS principle is violated, as the virtual world must accurately represent the real world. To address this issue, the stock-taking method should be implemented to update the virtual data. The stock-taking data will override the virtual data, ensuring that the virtual and real worlds are synchronized within the CPS system in production activities. Maintaining CPS functionality in operational workstations is crucial to producing accurate predictions of material needs.

Additionally, the data can be analyzed to gather valuable information, such as identifying operators who have not followed the SOP, tracking material loss, and monitoring material flow.

4. Conclusions

The implementation of a stock-taking method in the production monitoring system has proven to be an effective solution for addressing discrepancies between virtual and actual material data in labor-intensive manufacturing environments. Through periodic calibration of real-world stock data with virtual data in the CPS, the system successfully reduced the 2-3% discrepancies observed during manual operations. This calibration ensures more accurate material tracking, minimizes the impact of human error, and maintains the integrity of the CPS framework, where the virtual world must precisely mirror the real world. The stock-taking method provides a cost-effective and scalable solution for industries that rely on manual labor, enabling them to benefit from CPS technologies without the need for full automation. By synchronizing virtual and physical production elements, the system enhances decision-making capabilities and improves inventory management, ultimately leading to reduced material waste and greater production efficiency. Future work should focus on optimizing data analysis and expanding the system's capabilities to handle more complex production scenarios. Additional efforts could also be directed toward automating parts of the stock-taking process, further minimizing human intervention and improving the accuracy of material predictions. This study highlights the importance of integrating CPS with practical solutions like stock-taking to drive productivity and operational excellence in manufacturing sectors, particularly in developing countries.

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