International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

Information Technology based on Industry 5.0 Human Place into IoT- and CPS-based Industrial Systems

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Submitted: 12/12/2023 **Revised:** 24/01/2024 **Accepted:** 03/02/2024

Abstract: Information technology is developing at a breakneck pace in anticipation of Industry 5.0, whereas art design is founded on inventiveness and creativity. The big data age has begun as a result of the revolutionary development of big data technology. The main trend is to promote resources, tools, and big data thinking. It is a significant manifestation of creative thought, which explores the connection between art and design and is closely related to art design. However, ignoring the social and human factors, they have up until now primarily been fueled by technological advancements. The connected innovations of Human-Cyber-Physical Systems are then outlined in this study, with a focus on their applications in Emotional Intelligence (EI). These primarily comprise system design, theoretical evaluation, methodology development, and application predictions. Future development and research directions for HCPS are based on the human-in-the-loop idea and digital transformation, both of which can significantly enhance the system's performance. In the end, an integrated and complete contemporary power grid is created by more robustly achieving the ideal system efficiency of EI with the help of HCPS. These study findings demonstrate the complementary nature of the design, art, and cultural and creative sectors.

Keywords: *CPS, Emotional Intelligence, Information technology, Human-Cyber-Physical Systems*

1. Introduction

The global web of objects, on the other hand, links items—that are, IP-enabled products and gadgets—with the internet. The primary distinction between them is this. CPS is therefore an essential component of the Web of Things [1]; therefore WSAN laws are essential for SCPS with a diversified structure. Industry 5.0 uses a Bluetooth distributed management platform, which explains why. The Bluetooth Manufacturing Socializing Alliance's ZigBee, the World Federation of Automation's ISA100, and its Highway Addressable distance in an internationally dispersed company, the feedback control loop can be completed by utilizing Bluetooth HART in conjunction with the sensor protocol. With negligible communication faults and dynamic routing delays, the proposed SCPS should be incredibly dependable. This is because there won't be much interference from the workers' hands. It is suggested that through their integrated inventive cores, different types of SCPSs can be linked to an intelligent grid.

Industry 5.0 refers to an Internet-based ecosystem that encompasses several industries such as education, research and technology, healthcare, business, financing, and tourist attractions. Education research, creativity, development, evaluation, modeling, production, communication, marketing, transportation, and other activities are all integrated into software that can be shared or accessed online. Connectivity creates a foundation for the iterative, sustained updating and updating of standardized production methods and labor skills. A review-based conversation about the possible applications and supporting innovations of Industry 5.0 is provided by a survey on the technologies that enable in Industry 5.0, which aims to provide the first Industry 5.0 inquiry. Recently, new definitions and ideas were developed with assistance from researchers and business specialists. The second uses building condition tracking, where CPS can be employed as a warning system to monitor the state of old buildings, pathways, relationships, and roads.

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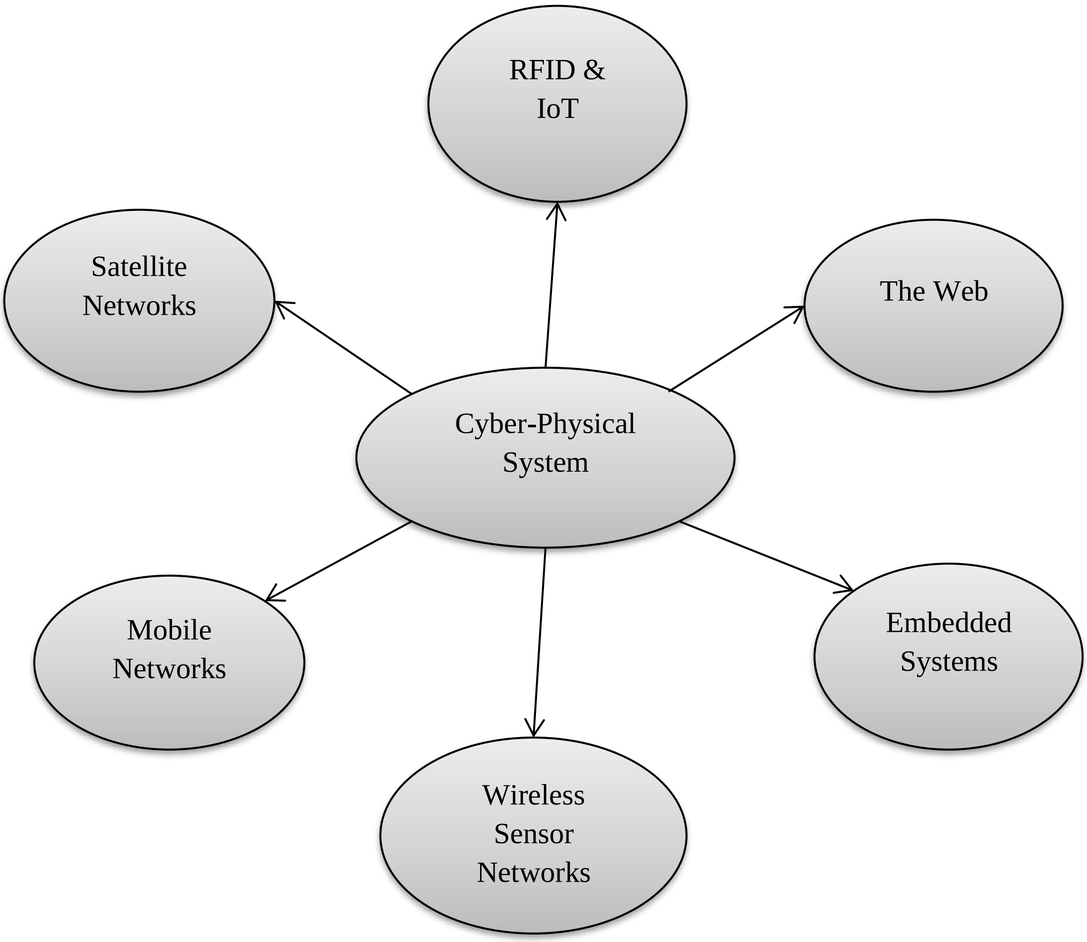

Fig. 1.1. Components of Cyber-Physical Systems at Large Scale

However, another option for networks of physical events is the Wireless Sensor Networks (WSNs) model, which enables the control and observation of environmental physical phenomena through sensors.

Other options took into account using mobile phones with sensors to monitor commonplace objects via cellular networks. These strategies are all included in the notion of Cyber-Physical Systems (CPS) that is systems that are set up across wide geographic regions and often comprise a large number of dispersed computer devices that are closely integrated with their physical surroundings. The primary parts of cyber-physical systems are shown in Figure 1.1 [2]. The current state of these newly developed cyber-physical systems makes one think of the years immediately before the Internet was created when networks were dispersed and private primarily for lack of rules. Comparably, CPS is presently dispersed throughout private networks, each of which carries out certain functions in the context in which it functions. How to enable the connectivity and interoperability of all these dispersed networked embedded devices into a single large-scale system that meets all of their criteria is the primary design issue of CPS. The establishment of a single system for cyber-physical systems is hampered by several issues. The suggested incentive scheme is predicated on the recruiter and applicant conditions, which turn into an optimization problem for quality assessment that is resolved by the authors' polynomial-time greedy approximations approach. The simulation-based research is finished and quite fascinating. Ensuring security is one of the issues that the IoT research field needs to address [3]. This includes issues with cyberattacks and other malicious assaults, in addition to issues with unauthorized and/or damaging actions on devices and/or infrastructures.

Surprisingly, the diversity of IoT scenarios—various connectivity hardware and software, computing limitations in the nodes, etc.—has prevented this issue from being thoroughly researched.

The relevant architectural research and foundational research for putting CPS into practice will be covered in Section 2. In Section 3, a framework for dynamically reconfiguring CPS-based shop floors will be presented. The results of the suggested system will be explained in Section 4. Section 5 will conclude this with some conclusions.

2. Literature Review

El-Haouzi, H. B., et.al [4] When discussing the emerging concept of the new robotic production systems created with CPS and IoT, these standards are once more in jeopardy. It has already been observed that these decentralized internet-based systems introduce path dependencies that could limit the automation potential for alternate work organization models. There is limited room for "re-automation" about human intervention in work processes if technological and human elements are not considered concurrently during the design phase. Though it is relatively new, the notion of CPS has significant appeal in the scientific community because of its vast range of potential applications. It's also frequently linked to the Internet of Things, which debuted a little early in the decade.

Valette, E., et.al [5] The organisational level of work was fundamentally impacted by the implementation of CIM systems in the 1980s. On the one hand, the computerization of work processes gave rise to the idea of fully automated, workforce-free factories. On the other hand, a conversation concerning the expanding and interdependent range of human actions inside working processes was sparked by the strict technical requirements. A work organization that strictly enforces human-machine interaction within a defined workspace and is reliant on technological constraints and logical production lines is referred to as "restrictive." When taking into account the assistance of capable and accountable workers who ought to be actively participating in the manufacturing processes, this organization vanishes.

Wang, L., et.al [6] The networking of people, things, and virtual representations of them within intricately flexible socio-technic industrial systems will be the focus of future goals. Both IoT and CPS are viewed as crucial components for understanding and creating future industrial systems, as well as for the advancement of the digital society as a whole. The Japanese project Society 5.0, which was introduced in 2016 at the Japanese 5th Technology and Science Basic Plan at the German Centre for Office Automation, Information Technology, and Telecommunications, is among the most cutting-edge instances in this regard. This perspective sees the technological advancements of the fourth industrial revolution as a new fifth wave, defined by the information society that is integrated into every facet of the industrial and cultural landscapes.

Ryalat, M., et.al [7] Cyber-physical systems are composites of physical and virtual spaces that integrate calculation, socialising, and physical assets to form a communication interface between the physical and digital realms. Although definitions of CPS might differ depending on viewpoints and experiences, it is widely accepted that hardware and cyber software constitute the connectivity between the physical and virtual worlds. Industry 4.0's central component, CPS, relies on the intelligent administration of connections between its computational and physical parts, leveraging cutting-edge technology in both domains. CPPSs have been applied in the energy, healthcare, and automotive sectors, among others. It has been extensively stated that more research on the long-term sustainability of CPPS is needed to achieve smart manufacturing, complete life cycle, and improve transportation, layout, efficiency, and upkeep.

Yin, D., et.al [8] Current research indicates that D-CPSS is still in its early stages of development; the majority of these studies have concentrated on the interplay between tri-space. The interconnections between the tri-space were absent from the conceptual framework for CPSS, even though a data-centric approach had been suggested. Most current studies focused on CPSS enabling smart manufacturing or wise manufacturing; nevertheless, few literatures examined CPSS in the setting of social manufacturing. Because social, physical, and cyberspaces interact and depend on one another, social production gets its name. The majority of studies used the term "social space" in CPSS to refer to people individually rather than in terms of social spaces.

Zhou, Y., et.al [9] Large-scale simulations are used to assess the idea, and the outcomes confirm the performance benefits in comparison to other baselines. The authors' first suggestion for energy management with Twitter integration is a combined citizen sensing and actuation platform. The experiment demonstrates that energy usage can be lowered by an average of 24%. The authors suggest that the introduction of citizen actuation is good for enhancing energy utilization. Subsequently, the authors give a framework for citizen actuation in which CPSSs can designate appropriate occupants to receive tasks. They also describe how occupants are chosen based on social media profile traits.

Guo, Z., Zhang, Y., et.al [10] Given that the hypothesis used to distinguish between the tissue signal and the blood scatterer signal was based on their distinct spectrum contents, only the temporal information has been used in any of these techniques. However, it is also apparent that the tissue signal's spatial properties differ from blood dispersion'. Tissue movement towards the transducer can be roughly represented by a shift in the RF information only along one M-mode line. One way to explain this is the fact that tissue is far less flexible than red blood cell arrangements in plasma; a tiny movement in tissue can be interpreted as a change in the spatial orientation of a speckle pattern, while a movement in red blood cells suggests that the scatterers have been rearranged, producing a distinct speckle pattern.

3. Methods and Materials

3.1 Requirements for Integrating Human–CPS

This section outlines the needs that must be taken into account while creating a human-CPS interface for an Internet of Things middleware, along with sample design approaches from the available research. Next, we associate these specifications with an Industrial-IoT use case. a succinct explanation of the key integration criteria for each of the ideas linked to the human–CPS interaction.

3.1.1. Capacity to Comprehend Human Traits

Knowing the differences between people and other system parts is the first step towards integrating people into an Industry 4.0 CPS.

- **Cognitive skills:** Compared to software individuals, humans have different mental capacities for observation, processing, and responding to problems.
- **Regularity:** To adjust to varying circumstances, humans carry out the same work in a variety of ways. They might also come up with creative solutions in the process. Additionally, when working on a task, they could become distracted or decide not to follow directions. Humans are significantly more unpredictable than machines due to these dynamic behaviors.
- **Fluid motivation:** Humans need rewards. Even after agreeing to complete a task, a person may not follow through without incentive.

These abstracted traits can be expanded upon or classified in a variety of ways, even though they capture many significant aspects of the human experience. More human qualities must be taken into consideration to ensure both the efficiency of the process and the security of the human workers as a result of the lifting of limitations on physical human–machine interaction, especially since I4.0 focuses on the collaborative relationship of human participants with machinery nearby [11]. By simulating human workers' preferences for workloads, the authors can allocate labor more effectively. Similarly, we demonstrate in our earlier work that the effectiveness of human–robot cooperation in a manufacturing procedure is positively impacted when a robotic system takes into account a human worker's fluctuating availability, drive, capacity, and tastes for cooperation when making decisions.

3.1.2. Endorsement of various human roles

Determining the human participants in the natural world and their interactions with machines, computers, and other people is a crucial step in the human–CPS integration process in smart manufacturing. Human control, human tracking, and a composite system that considers both direct human engagement and human sensing are the three primary categories under which the possible human–CPS relationships are outlined in the HiTL (Human-in-the-Loop) concept. The writers of present a classification of human jobs based on how people contribute to the smart manufacturing facility, based on this taxonomy offered for the HiTL model. Listed below are these four primary groups:

- Information purchase: It is considered that people are sensors that send information to the CPS.
- Condition deduction: Through their cognitive powers, handheld devices, or smart watches, humans give the system the ability to analyse data.
- Government and systems affecting: By assessing people's physical and mental health, CPS modifies its operations to meet the needs of people.
- Actuating: Using their cooperative actuation skills, humans solve issues or finish smart manufacturing tasks.

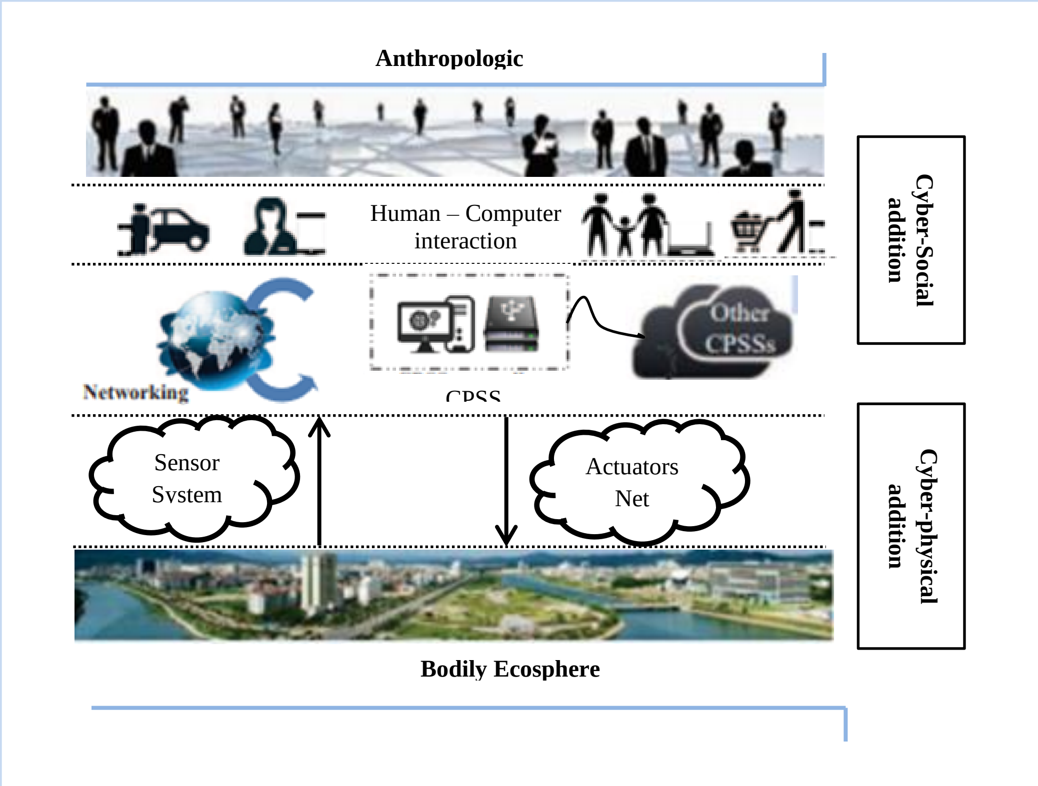

Fig. 3.1. The CPSS's layered architecture

In actuality, CPSS is a young, multidisciplinary field of study. However, after looking into the literature, we discover that the multilayered structure of the CPSS in Figure 3.1—which is essentially based on the industry and academic standards for CPSs—has been authorized by the academic circles. There is a foundation in place that makes it possible to use CPSSs in practice. In addition, the CPS system needs to be updated with the various job descriptions held by people working in the smart factory. It is easier to add additional human actors to the system when the default actions, rights, and responsibilities of different work descriptions are included. In our example of a "pick-assemble-place" operation, employees function as actuators assisted by machines, acting on data provided by the manufacturing process monitoring agent. A recording device and a human activity detection agent track human behavior to infer a person's state.

3.1.3. Human integration interfaces' reuse

Interface reusability in the context of human–CPS integration refers to the ability of software components and interfaces created for human integration to be flexible enough to adjust to various applications, roles played by humans, and settings. Many modelling approaches that offer abstract descriptions of constituent types for data models can be used to build reusable interfaces. In order to guarantee reusability, the data models must operate without a hitch in both virtual and physical worlds.

An object-oriented data model is used to implement the Digital Twin notion, and an example of a reusable interface is shown. An additional instance can be discovered in which the authors developed reusable functional block-based modules that have appropriate data and event inputs for use in a CPS for in-person human-robot interaction. Another instance of how to construct reusable solutions is to utilize ontologies to describe human functions and CPS aspects [12]. These ontologies give standardized data to machines so they can easily comprehend the material of the offerings. One way to create a knowledge base with semantic descriptions is to include smart factory human roles in the specifications. These roles can be identified by other entities, allowing for interactions between them. To implement our smart factory, use case, we also concentrated on ontology-based data modeling in our structure.

3.2 Information Technology

It plays a significant role in CPS in the manufacturing sector. According to this perspective, there are two categories of major challenges: cyber-centered and human-centered.

3.2.1. Human-focused

Current production control and optimization issues cannot be resolved by the methods now in use. Comprehensive production control (HPC) is necessary. To succeed in the emerging CPS to produce goods in Industry 4.0, human-centric IT development is necessary. The infrastructure of smart spaces is dynamic due to the individualized product and the new modular, adaptable, and changeable production paradigm. Because of this, the factory frequently needs a human worker with broader skills to comprehend and handle the various relationships between a physical thing and its digital counterparts. Furthermore, augmented reality (AR)-based fast learning techniques are becoming more and more significant; these kinds of techniques are necessary for machine installation, oversight, and management.

3.2.2. Cyber-focused

The adoption of cloud computing, handheld devices, service-oriented architectures (SOA), IoT, and IT-based user interfaces becomes unavoidable. Enabling intelligent industrial devices to converse and comprehend one another is the challenge of Industry 4.0. All data (and services) about and from an actual production component must be represented digitally for this to happen. Sensing corporate vision, software-enabled hybrid solutions, and sense compute-control (SCC) systems are becoming critical, complex architectures in the cyber component space. These areas are best served by the model-driven software engineering (MDSE) approach. The data integration also demonstrates the requirements for a machine-readable semantic formalization to transform Automation ML and combine APS with ERP. Systems in Industry 4.0 must make decisions, set off events, and manage one another on their own.

Additionally, the automation of recently accepted Internet technology presents a difficulty. Additionally, (close to) real-time optimization is necessary to employ cyber components for managing hardware, although it is significant work.

3.3 CPS methods for production

One of the main goals of our evaluation work is to ascertain the various methods utilized in Industry 4.0 production to comply with CPS. Three perspectives are available for observing the methods of CPS for production: sensor-based, data-driven, and CPS-focused computer methods. Sensor-based systems focus primarily on real-time routing and data sharing, while data-driven approaches leverage digital representations based on linguistic knowledge and cognitive approaches. Furthermore, concepts like patterns, IoT-enabled, dynamic reorganization, agent-based systems, human-machine interaction, and so forth are the source of CPS-oriented software techniques. Various articles related to the three primary elements (HC, CC, and PC).

3.3.1. CPS-focused Software Methodologies

One key component of the manufacturing CPS paradigm is the humanist software interface. To construct industrial automation systems (IASs) and service-oriented architectures (SOA), anthropocentric cyber-physical systems (ACPS) require a reference model in the form of UML modeling. For manufacturing automation, this model may include the PC, CC, and HC. In a production setting, personal scheduling and planning techniques keep an eye on the backlog of orders and estimate the true workload to make the most use of labor time. Additionally, the human-machine interface (HMI) and workflow manager (WFM) are regarded as the core components of the modular production system design.

A novel user interface method can be designed to employ different related technologies for a set of human-machine interactions. Nonetheless, the adoption of a mixed-reality-based instructional strategy is required for future industries to require human workers to have a wider range of skills. It blends digital content visualization with real-world items using augmented reality (AR). Furthermore, *Holobuilder* is designed to serve as a new horizontal platform for Industry 4.0 instructive education manual artifacts.

3.3.2. Cyber component software techniques

A crucial component of the cyber component (CC) is the user interface (UI), which integrates the PC and HC into the CPS for production. A pattern-based business model monitors various risks and modifications to the production resources, manufacturing procedures, and manufacturing environment of cyber-physical production systems (CPPS). The automatic creation of the mechatronic components' IoT-compliant interface is supported by a technique known as UML4IoT [13]. All parties involved in the smart manufacturing facility are more actively involved thanks to the meta-process. Visual computing services are now a need in the manufacturing sector of the Industrial Web.

Resource convergence and smart negotiation are handled using agent-based techniques, while software engineering is presented as a method for characterizing advanced planning systems (APS).

Moreover, a distributed hash table-based and semantics web-based federated architecture is described for Industry 4.0 services organization and location.

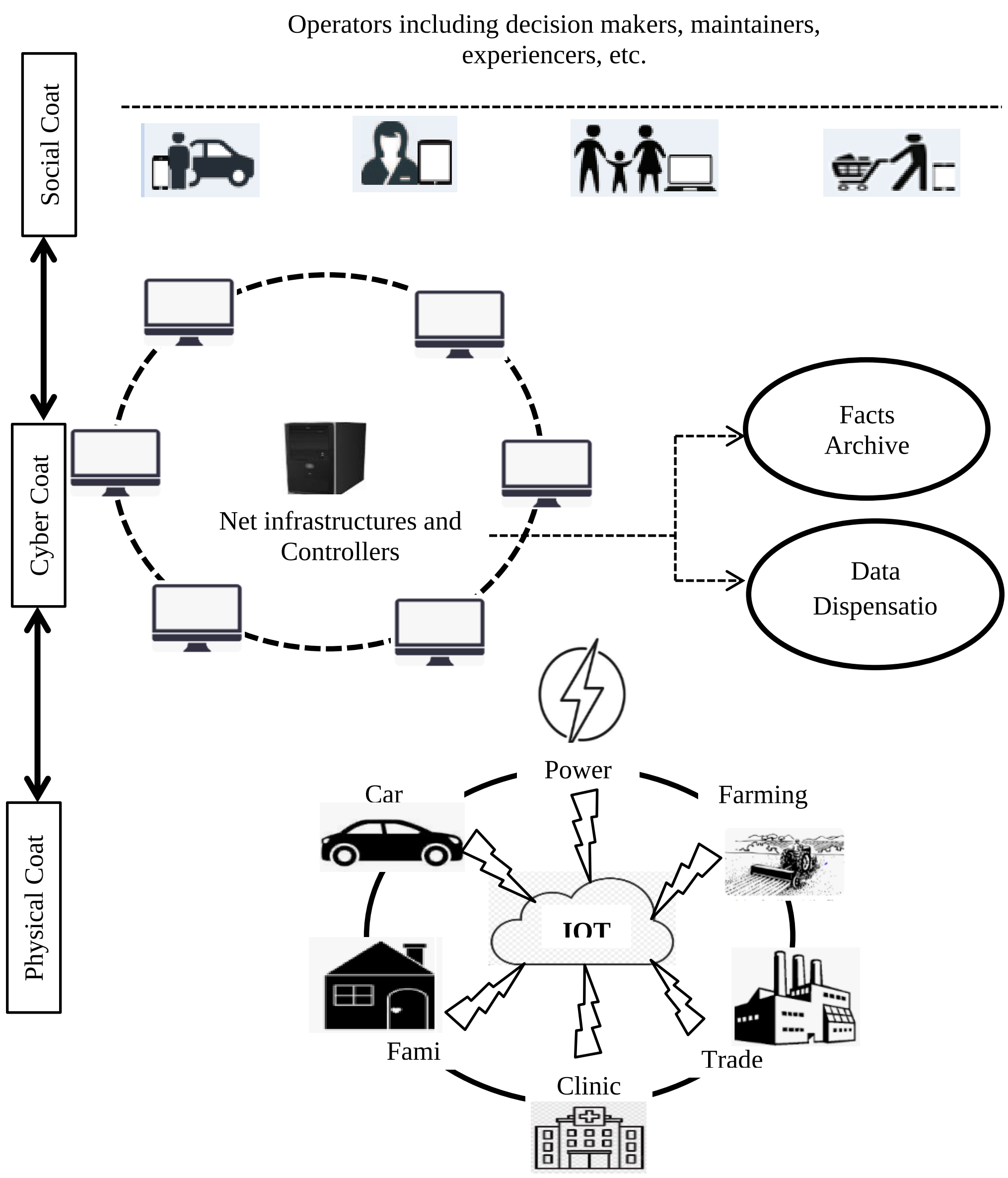

Fig. 3.2. A CPSS-based virtualized infrastructure

Four different types of virtual networks are produced by placing edge computing servers strategically or by taking advantage of the storage capacity at each CPSS controller. Various services can be handled by these virtual networks based on the needs of the users and gadgets in CPSSs.

- **Conventional CPSS network:**

Although CPSSs offer a broad range of applications, these domains may share similar communication service needs.

Certain communication services, including decision feedback, may be provided via the conventional virtualized CPSS network without processing and storage because of its safety and privacy features.

- **Networks CPSS with function of caching:**

The emulated CPSS networking with caching function can serve some popular huge files, like photo collection files, install packages, tool books, and apps, since they may be called often in the not too distant future and have some cache significance.

- **Network CPSS with computational capability:**

The virtualized CPSS network with computation function can be used without the need for storage to guarantee privacy for computation jobs like face and QR code detection.

- **CPSS network featuring compute and caching functions:**

The simulated CPSS system with computing and caching functions provides the video acquisition services. With the help of edge computing servers, the gathered video contents can be transcoded in real time to adapt to network conditions, and some of the more popular ones can be stored to reduce the workload associated with backhaul bandwidth. It is possible to set up real-time navigation for virtual smart traffic in these virtualized networks. Global traffic map storage can be done at different network nodes, and real-time navigational route guidance is provided by computing edge servers.

For CPSSs, the suggested virtualization architecture is shown in Figure 3.2. There are three layers that make up the entire design:

Using generic hardware and cutting-edge software with WNV support helps network operators spend less on capital expenses (CAPEX) and operating expenses (OPEX). By separating the physical structures from services, WNV allows devices with various service needs to connect to multiple virtual networks even though they are sharing the same facilities, increasing system usefulness. By doing this, the virus can lower the CPSS network's building costs. The growth and upgrading of applications and networks can be realized without replacing the network's infrastructure since SDN abstracts and standardizes the control plane.

Thus, WNV can encourage the growth of CPSSs with the help of SDN. WNV can improve resource utilization by offering services for various business kinds while making use of both the restricted network resources and the existing facilities. Furthermore, the low power use, real-time performance, and transmit reliability demands for mobile communications can be better met with a sensible standardized multi-resource installation.

4. Implementation and Experimental Results

Researchers used Matlab Sim Event, a discrete event simulation programmed from MathWorks, to develop the model in this research. The verification and validation of the simulation model as well as some first findings are covered in the remaining portion of this section. Implementing a CPS-based environment requires an internet-based system that can manage data collected in an organized manner using smart objects like actuators, sensors, and industrial wiring. However, since there isn't a setting that can get data from factories using sensors, simulation software is employed in the present research to collect information.

Table 1. The input and output data set characteristics

	Input	**Output**
Normal state	P	Training results
Abnormal Detection	Q	Tests results

Proceed by the procedure shown in Figure 4.1, taking into account the input/output variables defined in Table 1. As previously said, it is considered that the machine is operating normally if there is no change in the servicing time. Conversely, in the event of a shift, it is considered an anomalous circumstance. Because of this, the output data is pre- and post-changed to represent training and test outcomes.

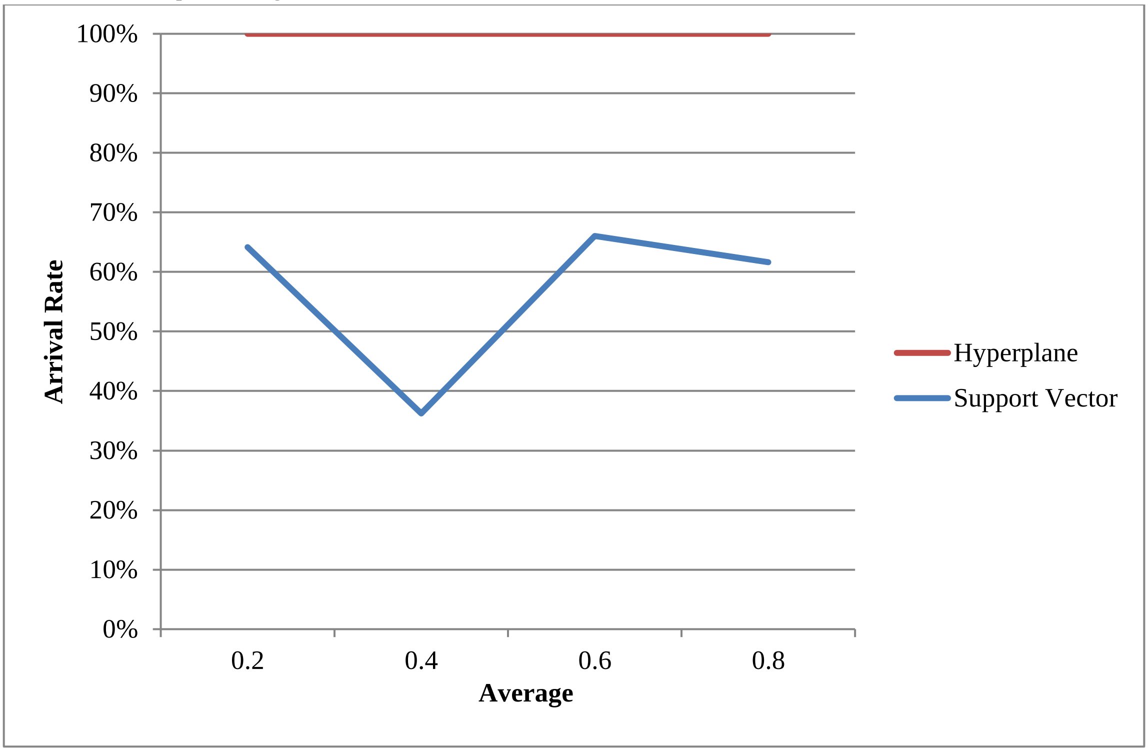

Fig. 4.1. Use SVM to identify odd situations

The model's output following training is displayed in Box 1. The output indicates that the object is the dual SVM problem's optimal goal value. The notation SV stands for several vectors that support, while BSV stands for bounded support vectors.

Before beginning the manufacturing system's reconfiguration procedure, we compared the server (before and after the abnormal situation happened to confirm the effectiveness of the SVM-based dynamic reconfiguration process that was proposed. An abnormal condition occurs when the machine's processing rate is overwhelmed or when a drop in speed causes the service rate to alter [14, 15]. The anomalous circumstance occurred randomly at a time and place with a processing time of 8,000 seconds.

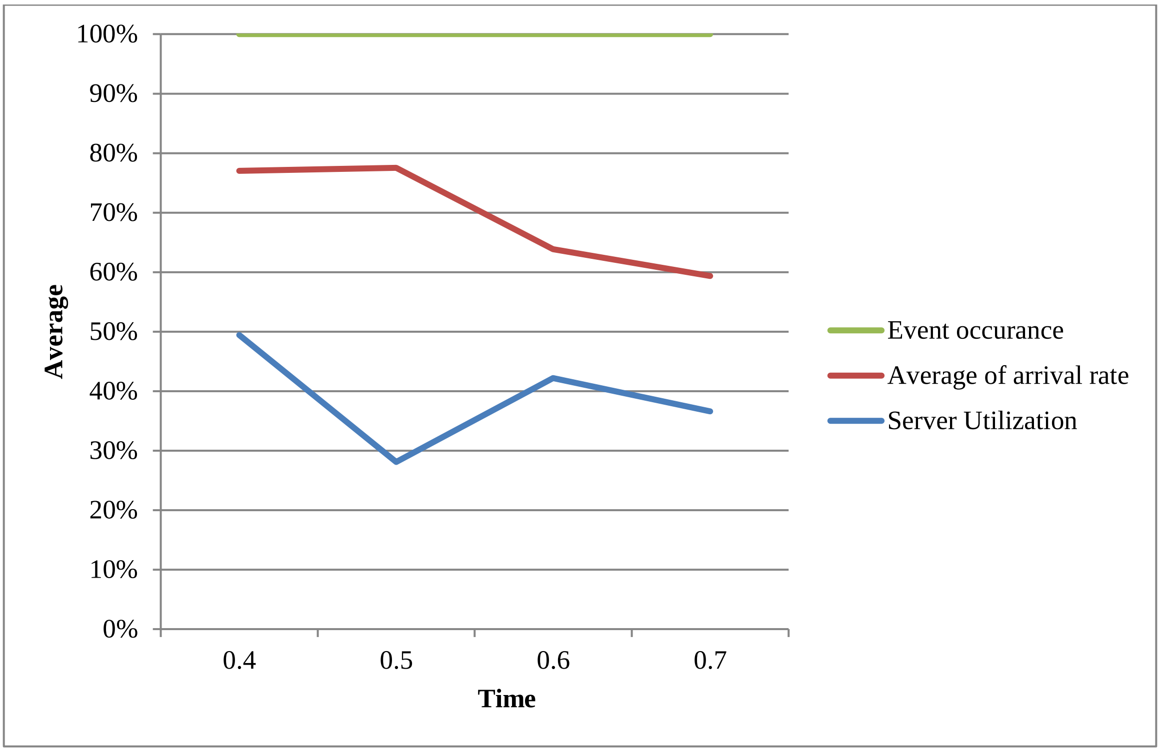

Fig. 4.2. Results of the simulation for server usage in the absence of an event

Figure 4.2 illustrates the fluctuation of after events (a) and (b) at t = 1,000 and 3,000. Conditions that cause the machine to slow down or get overloaded are considered abnormal and lower. Figure 4.1 labels the median value of this as "class 2." When an anomalous circumstance arises and the manufacturing route is altered, the production route is switched to the nearby machine at t = 8,000 when the abnormal condition on machines 1–3 happened at q = 2,000 and the average was outside of α ± threshold.

Because Q has not surpassed the barrier, the production path on machines 2-3 has remained unchanged since the abnormal circumstance at t = 3,000. After entering machines 2-3, the product of machines 1–3 rose at t = 8000. Identifying machines 1–3 as errors in the model test shows that the model used for simulation has been rebuilt.

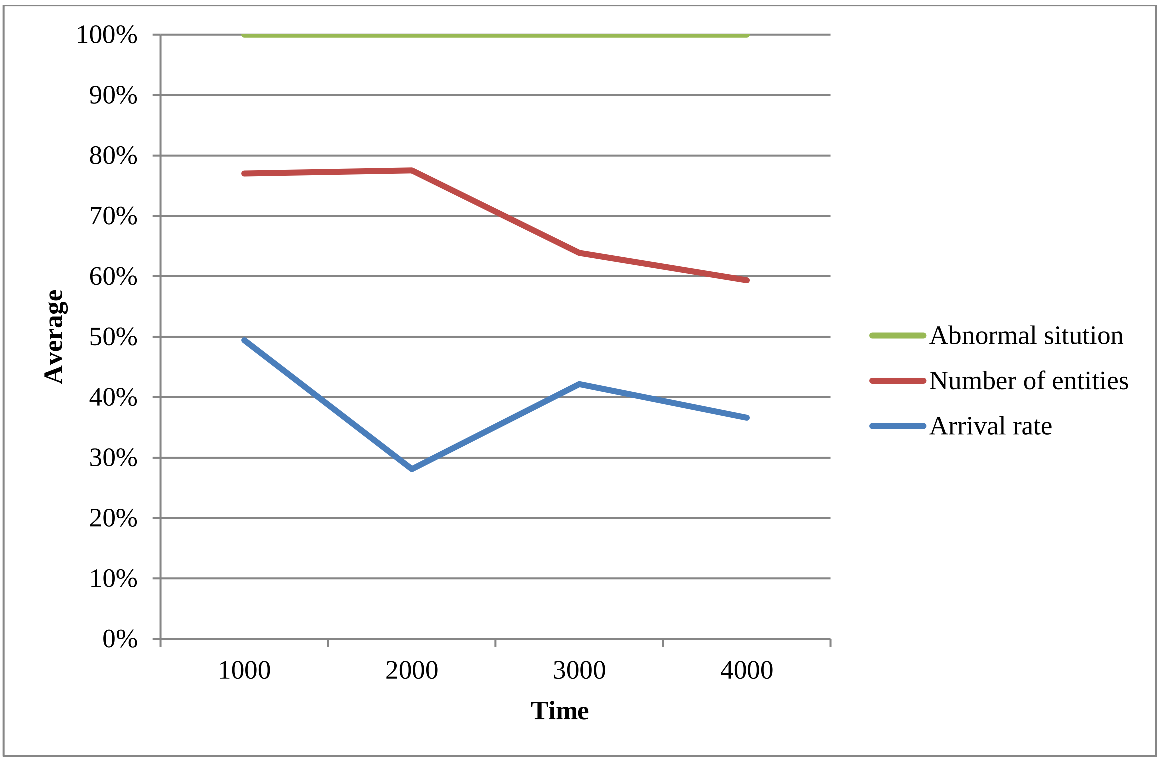

Fig. 4.3. When an abnormal condition arises, the utilization happens when the manufacturing route changes

When no anomalies arise, Figure 4.3 displays the server of machines 1-3 and 2-3. For every machine, when nothing unusual happened, it was found that was comparable. The mean value was categorized as "economic status 1" in Figure 4.2.

A variety of items created after an unusual event and a modification to the manufacturing path are depicted in Figure 4.3 indicates that machine 1–3 stops at t = 4,000, and (b) indicates that more items are produced as a result of the products moving from machine 1–3 to machine 2–3. This shows that the reconstruction of the model from simulation has taken place.

In this paper, we modeled and tested a conveyor belt manufacturing process based on the M/D/1 queue for the creation of CPS. We then used SVM to determine the incidence of abnormal situations caused by equipment overload at the shop floor, and the M/D/1 queue is used as input parameters when training an SVM. Determining whether the problem was normal or pathological was thus achievable. The production process was reconfigured to address any anomalies.

5. Conclusions

The framework employed in the present research increases practitioners' comprehension of areas of influence inside their organization by providing a clear grasp of the service system that surrounds CPS applications. Furthermore, the identified problems for service system design offer practitioners a roadmap for understanding which pertinent concerns to take into account to fully utilize CPS inside service systems and avoid impending roadblocks. Major hazards in CPS-based service system design will probably be avoided if developers consider the study's primary findings and direct their development efforts accordingly.

If an anomalous circumstance arose in a manufacturing system based on CPS, this allowed for a flexible system.

Future studies will examine how to include various decision-making processes to leverage numerous decisions. Because CPS is a technology adaptable to multiple fields as well as Industry 4.0 and vital in fields needing prediction and self-healing, it is anticipated that it will be valuable for more research and development.

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