Analysis of CPS Applications in the Healthcare

[1]Megan Alex and [2]Alyssa Thompson
[1,2]School of Allied Health, University of Alaska Anchorage, Anchorage, AK 99508, United States.
[1]alexmegan433@gmail.com, [2]alyssastd@uaa.alaska.com

Correspondence should be addressed to Megan Alex : alexmegan433@gmail.com.

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Abstract – Cyber-physical system denotes the framework, which combines computational and communication capabilities with physical processes. It can make our interactions with others smarter. Because robust sensing capacity is among the main motivating elements for Cyber-physical systems (CPS)implementations, Wireless Sensor Networks (WSN) could be an integral part of CPS. There are many problems that need to be fixed before CPS can be considered more than an emerging technology. To date, only a handful of CPS applications have been proposed for use in healthcare settings, and these applications lack the adaptability that would come from integrating technologies like computational services with sensor nodes. This paper provides a comprehensive overview of the various healthcare CPS implementations that have been recommended thus far in both the academic and commercial sectors. In addition, a thorough classification is provided, detailing the various parts and procedures needed to implement CPS in healthcare environment. The classification not only draws attention to the overlaps and distinctions between WSN and Cloud Computing as applied to CPS for healthcare, but it also pinpoints the research gaps that exist between these two fields.

Keywords – Cyber-physical systems (CPS), Wireless Sensor Networks (WSN), Wireless Body Area Networks (WBANs).

I. INTRODUCTION

Cyber-physical systems (CPS) have lately garnered the attention of many academics from both the academic and industry domains as the next computer revolution. Since a CPS integrates communications and computations into a single, powerful unit, it marks a significant step forward in the development of computing. Similar to how the internet transformed interpersonal communication, cyber-physical technologies will radically alter how we interface with the physical domain. Research work into CPS was noted as the highest priority in 2008 by both the Data Science Foundation (DSF) and the U.S. President's Committee of Representatives on Technology and Science (see **Fig 1**). CPS offers a wide range of potential applications in various industries, from military and transportation to industry 4.0, energy, medicine, agribusiness, and more. A BMW, for instance, might be seen as a network of thousands of sensors and devices that engage with their physical environment and provide decision-support to different cyber systems by methods of communication, computation, control, strategic planning, etc. Here, we shown how CPS might transform our world from a physical process into a cyber system, enhancing our responsiveness, precision, and quality of life, among other measurables.

The concept of the cyber-physical system (CPS) has been gaining traction as a promising new field of study in recent years. It integrates digital and analog capabilities, including processing and communication, in the real environment. In 2008, CPS was designated as an NSF priority area, and the US President's Committee of Representatives on Research and Technology ranked it as their top research priority. Sensors, processors, and connections between nodes are crucial to CPS. Recent developments in WSN, medical devices, and Cloud Technology make CPS an attractive option for a variety of healthcare settings, from hospitals to patients' homes. These developments have the potential to enable CPS to monitor patients remotely and take corrective measures wherever they may be located. Numerous studies are being undertaken on medical sensors. Invaluable health data may be gathered from patients thanks to these sensors. The information is sent wirelessly to a gateway. Although wired sensors may be employed, transceivers provide more convenience and ease of use for both the caregivers and the patient. Clinicians may have access to the sensor data once they have been saved in a server. Because of the legal and ethical constraints placed on disclosing patient information, data security is of the utmost importance.

This means that data security must be a top priority throughout the design phase of a CPS infrastructure for healthcare systems. There are many other factors to think about as well, such as the need for somewhere to put and organize the mountain of data generated by thousands of clinical sensors. Therefore, it is important that database management solutions be both effective and trustworthy. All relevant medical records should be easily accessible to qualified medical professionals around the clock and in any location, since they may include information that might save a patient's life. Smart decision making feasible for large amounts of patient data also requires extensive computer resources, which is why healthcare apps tend to be so resource-intensive. However, there are significant limits on energy, computing power, and storage space in the systems of remote monitoring that gather the patient data. They are unable to store or handle massive amounts of data because they lack the necessary infrastructure.

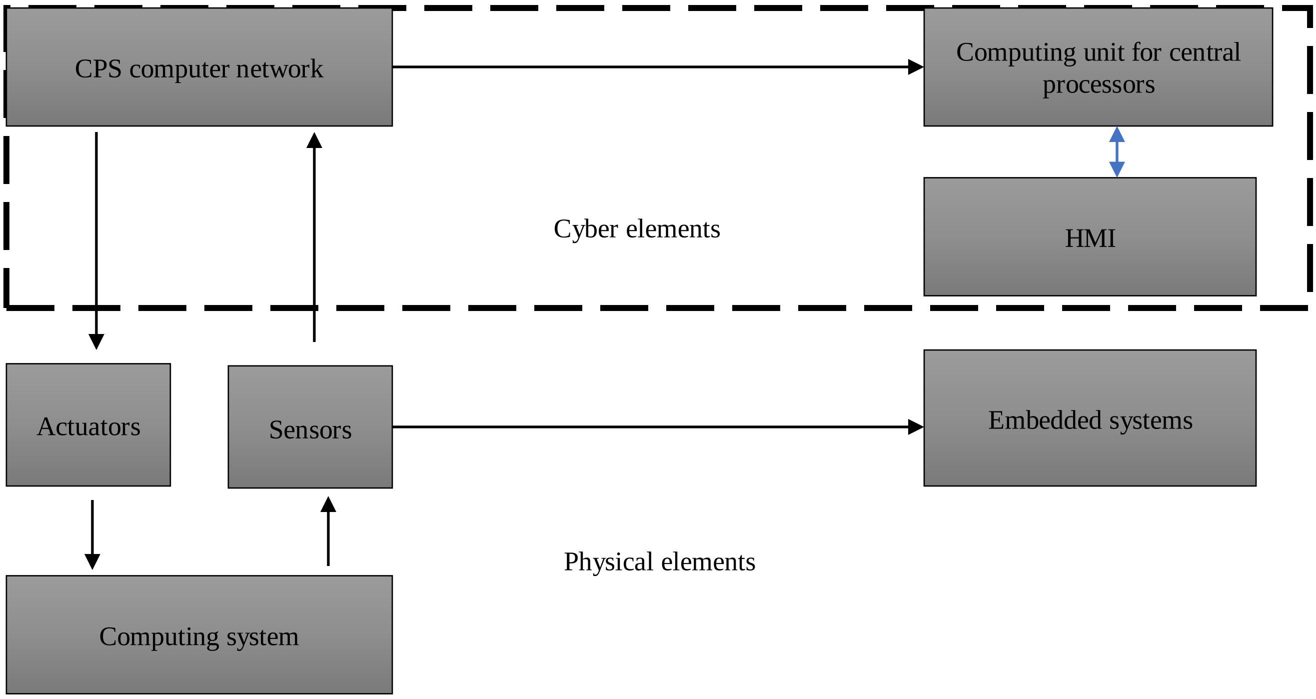

Fig 1. Cyber-physical systems according to the Data Science Foundation

Some of these problems may have answers in the form of services offered by cloud computing. Efforts are being made to enhance the system's scalability and make real-time data analysis possible via the use of cutting-edge Cloud Technology as the analytical foundation of CPS. The term "cloud computing" refers to a kind of IT infrastructure that may be accessed on demand from any location by any type of user, at any time. It's a service that provides various IT resources, such as servers, databases, networks, and applications, "as a service." "cloud" is characterized by Angeli and Masala [1] as "a distributed and parallel computing framework integrating a collection of virtualized and interconnected computer systems, which are dynamically presented and provisions as a single or multiple computational resources centered on SLA defined via the communications between the users and providers of services."

In light of these definitions, we may expect the cloud to exhibit the following qualities: Self-service, usage-based invoicing, adaptability, and individualized care are the four pillars of this model. Users like Cloud Computing because their data and programs can be accessed from any computer with an Internet connection, and because they don't have to download and install any software on their own machine to utilize it. In addition, Cloud Computing vendors provide a wide selection of APIs, design tools, and other software services for programmers. In this way, clients may migrate their computing needs to the cloud. Internet technologies (web services, service-oriented architectures), Distributed computing, system control (autonomous computing), and hardware (virtualizations, multicore processors) are all factors in the development of Computer Technology. In CPS, the cloud hosts the cyber (computing) processes while sensors monitor the physical environments.

Many questions remain unanswered because of the novelty of CPS technology. There are a number of problems that need to be addressed, including those related to real-time processing, data querying, data storage, and data security. The purpose of this study is, in part, to draw attention to some of the open concerns that remain in the field of CPS for healthcare, particularly with regard to issues like comprehensiveness, efficacy of communication, and precision of alarm production.

The remainder of the paper is organized as follows: Section II presents the research motivations and contribution. Section III presents a general overview of CPS in the healthcare sector. Section IV discusses the classification of CPS in the healthcare sector, while Section V presents classification-based mapping of medical CPS. Section VI ends the paper with a final remark of the whole research work.

II. RESEARCH MOTIVATION AND CONTRIBUTION

Motivation

The motivation behind this research integrates: (i) as an emergent and promising field, a vivid usability and demarcation of various elements of CPS for medical provision is vital; (ii) As no CPS are prevailing, a crucial study of the related CPS in the clinical system suggested to date are essential for the establishment of medical applications; and (iii) even though some contributions on CPS, nonetheless, there are no contributions concerning CPS in the medical sector to date.

Contribution

This contribution reflects on: (i) a critical survey of prevailing CPS purposed for medical applications; (ii) depictions of CPS cases with reference to the fundamental elements e.g., controllers/actuators, security, communications, computations, data management, sensing, architecture, and applications; (iii) a critical analysis of a classification that is related to CPS in the medical sector; and (iv) a conclusion of the issues related to the application of CPS in the medical sector.

III. GENERAL OVERVIEW OF CPS IN HEALTHCARE

This sector provides a general overview of CPS, its elements and features.

Cyber-Physical System (CPS) Definition

The terminology"cyber-physical system" bridges the gap between the digital and the real. It can make interactions between people smarter. Physical equipment like cameras and sensors are combined with digital ones to create an evaluative system that can automatically adapt to changing conditions in the real world. CPS has several potential uses, including but not limited to intelligent medical advances, supported accommodation, pollution monitoring, and traffic control. Integrating WSN with Cloud Computing is a crucial aspect of CPS. The CPS has been the subject of some research for use in medical settings. Jeong and Park [2] suggested CPS designs that explored many applications, including assisted care and network surveillance. The authors stress the importance of the CPS designs capturing a wide range of physical data, trustworthy data analysis, activity recognition, and privacy.

Benefits of Cyber-Physical Systems (CPS)

Table 1. lists some of the advantages of CPS that make it a plausible option for merging the real and virtual worlds.

Table 1. Benefits of CPS

Potential CPS benefit	Details
Network Integration.	CPS can communicate with both WSNs and Cloud Services. If so, then this would ensure that the network complies with all applicable requirements. To achieve CPS, a number of computing nodes communicate with one another through various channels of data transmission. Coordinating and management over the scheduling of network operations, as well as fault tolerances, are all provided by CPS as part of the system assimilation features provided by CPS.
Interaction between Human and System	It is essential for decision making to model and measure situational awareness, which is the human perspective of the systems and the variations in its surrounding characteristics. This is crucial for adaptive and complicated systems. Because people are notoriously hard to simulate in isolation, some CPSs build them right in, simplifying interaction.
Dealing with Certainty	Proof of the validity and reliability of a design is the approach to achieving certainty. Forensic proofs and thorough simulation and prototype testing are both acceptable forms of evidence. Because of this, CPS is built to adapt to changing conditions and function in an uncertain setting. By revealing previously hidden system behavior, CPS may help researchers improve their understanding of the system and create more robust designs.
Better System Performance	Detectors and cyber infrastructures work together closely in CPS, allowing for improved system performance via feedback and autonomous redesign. To further guarantee higher performance of the system, CPS makes use of many sensing units, various communication methods, a high-level computer language, and end-user management in addition to its superior computation resources and cybersecurity components.
Scalability	Through the use of Cloud Computing's scalability features, CPS may adapt the system to meet fluctuating demands. Users may get the tools they need without spending any extra money to do it. Considering that it involves both computational and physical processes, CPS is intrinsically heterogeneous. The physical realm may incorporate human intervention alongside biochemical processes, physical motion detection, and biochemical mechanisms. It's possible that the cyber domains may merge networking architecture, application software, and computer modeling into a single entity. Designs that scale to enormous sizes and foster an appreciation for complexity may be supported by the design techniques and tools made available via CPS.

Autonomy	The combination of sensors and the cloud allows CPS to provide independence. Closed-loop measuring systems are the norm in the realm of physical dynamics. Actuators and programs that influence physical processes are driven by the results of these assessments, which are evaluated in the cyber systems. In cyber networks, adaptive and often anticipatory control mechanisms are used.
Flexibility	In comparison to prior scientific research in Cloud Computing and WSN separately, today's CPS-based solutions provide far greater versatility.
Optimization	The current generation of biosensors and cloud infrastructures allows for significant improvements across many different use cases. This skill paves the door for CPS to perform comprehensive system optimization.

CPS in Healthcare

This section is dedicated to discussing cyber-physical systems with an emphasis on medical applications. CPS studies in the medical field are in their infancy at the moment. Combining active user inputs such as smart feedback systems and digitalized recording for patient data with the passive inputs of the users e.g., biomaterials as well as intelligent technologies in healthcare facilities may improve data collecting for effective decision making in CPS. There has been little systematic investigation into combining data collecting with decision-making systems in healthcare applications, making this an area of intense research interest. Miniaturized implanted connected devices, local area networks, programmed materials, and innovative manufacturing processes are all opportunities afforded by the use of CPS in healthcare. So, too, is the introduction of integrated interconnectivity of independent and adaptable devices.

While several CPS designs have been suggested in academic circles, far fewer have been developed for use in the healthcare sector. Although the notion of a healthcare CPS based on Service-Oriented Architecture (SOA) was introduced by Maurya and Mukherjee [3], it is missing an overall framework for its implementation. Secured CPS design for medicine using WSN-cloud integrative system was described by Yildirim and Tatar [4]. Medical CPS modeling and analysis was suggested by Chen [5]; nonetheless, it does not adequately address concerns about security and privacy.

IV. CLASSIFICATION OF CPS IN HEALTHCARE

A collection of taxonomies that defines and organizes CPS methods for healthcare delivery would be helpful. **Fig. 2** provides a synopsis of this kind of classification for CPS in health care system based on our review of the existing literature. It integrates the following components: e.g., controllers/actuators, security, communications, computations, data management, sensing, architecture, and applications. This section presents the elements in a detailed discussion of each.

Application.

Multiple settings in healthcare may benefit from CPS, including hospitals, assisted living facilities, and nursing homes for the elderly. The complexity of a system is heavily dependent on the nature of the intended use. Architectural components may need domain-specific structuring. A hospital's critical care unit is an example of a controlled environment where the design may include regulated aspects. However, in an aided living facility, it could be essential to integrate different automatic aspects into the design. When applied to the healthcare industry, CPS may be classified as either (a) controlled or (b) aided.

Aided

Health monitoring that does not interfere with a person's ability to lead their own life is an example of an assisted application. Using real-time biosensor data, physicians may better advise individual users. It might be feasible to care for and support an increasing number of individuals in both aided living facilities and homes by considering each person's unique medical needs into consideration. Loss of motor, sensory, and/or cognitive abilities may have a cumulative effect, rendering elderly people unable to care for themselves at home and necessitating institutionalization. There are significant monetary and emotional expenses as a result of this. Opportunities for enhancing the in-house autonomy as well as security, e.g., ANGELAH, may be facilitated by advances in computing technology.

Controlled

Deployment in a controlled setting includes settings like hospitals and critical care units, where skilled medical personnel are close at hand. There is strict and constant monitoring in a lab setting. Bedside sensors, biomaterials, and physicians' observations are only some of the sources of data that go into informing actions in hospitals. Medical processes and patient safety may benefit from interconnected closed-loop model that include human intervention. Care providers will be better informed to make choices regarding treatments thanks to the data provided by emerging technology designed to enable remote care of patients. The medical system might be transformed into a massive, complex, and safety-critical CPS with numerous benefits and difficulties if these two distinct areas were combined.

Architecture

The medical system's performance and reliability are heavily dependent on the CPS design. The CPS for medical applications may be facilitated by designing the architecture around the area of the program, the requirements of the users' data, and the connectivity of the many systems. There are three distinguishing features of CPS architecture: (i) infrastructures, (ii) data requirements, and (iii) composition.

Infrastructures

Infrastructures like servers and the cloud may inform the development of healthcare CPS architectures. Newer works take use of the cloud-based architecture for flexibility, cost efficiency, and availability, whereas server-based architecture is best suited for modest architecture and needs individual management. Cyber and physiological elements might be susceptible owing to numerous issues related to complexity and resource restrictions; hence, particular efforts are essential when building CPS for medical applications.

Data Requirements

Input data, historical data, and data output are all sorts of information that need to be managed while administering a CPS architecture in the healthcare industry. The amount of information collected in healthcare might vary widely across various biosensors. Data may range from the most basic, like temperature readings, to the very complex, like those generated by MRI (Magnetic Resonance Imaging), and both need to be administered. According to Tripathi, Talak and Modiano [6], the means of information gathering and dissemination may change depending on the nature of the application. Internal temperature and blood volume are instances of low data rate applications, whereas increased concentration surface EMG (Electromyogram) is an indicator of high bandwidth use. Moreover, it is possible that retrieval of previously stored data will be required. Light and heavy data needs may therefore be distinguished within the framework of the infrastructure.

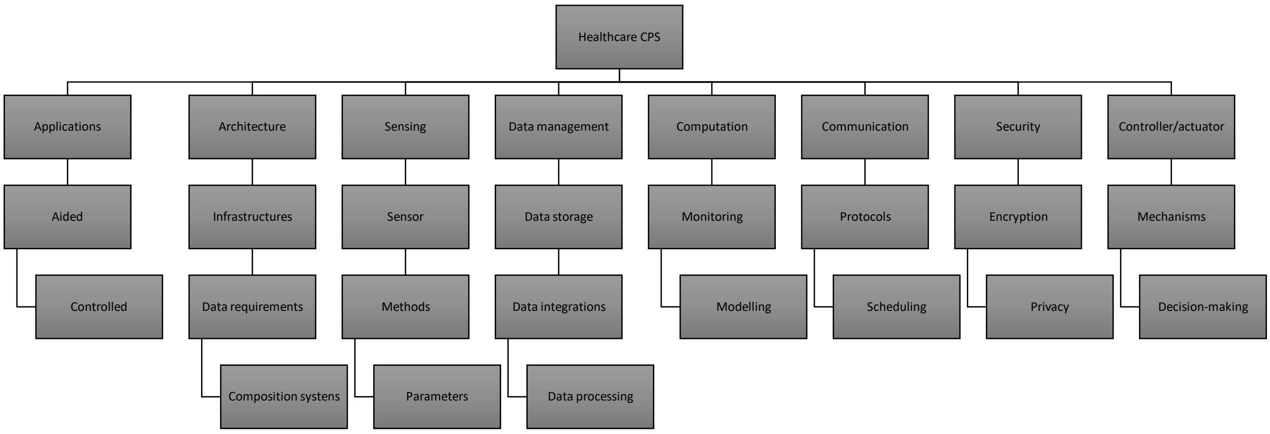

Fig. 2. Classification of CPS for the healthcare setting

Composition

Computing and networking functions are commonly required to run in parallel in medical CPS design. The system architecture's ability to determine the system's composition in relation to its intended use is essential. The apps must be constructed either automatically or explicitly based on the settings of the system or the needs of the end user. The system architecture might be seen as user-defined; for instance, Elkerton [7] developed an intelligent checklist to aid and guide human users throughout activities. The system also facilitates communication between the user and the various hardware components and software programs. To achieve a dynamic composition, computational and communication activities would need to be carried out automatically.

Sensing

Sensing is used to detect the presence of CPS in medical settings. Important physiological data is collected by biomedical sensors and then sent into the data and transmission system. Since the data that are felt are employed as input parameters, sensing is a primary problem for healthcare applications. In many cases, patients experience discomfort upon sensing. If a diabetic patient wants to check their blood glucose level (BGL), for instance, they have to prick their finger and obtain a sample. To address this, radio-based sensors are used in a noninvasive technique of BGL monitoring. From a sensing point of view, the components are (i) sensing design, (ii) technique, and (iii) parameters.

Sensing design

Sensor density and variety may vary greatly in medical settings. There is some flexibility in the composition of the sensors. The health state of a population may be monitored by a single-parameter sensing device or by many sensors attached to an individual. The sensing approach used has a significant impact on the overall system complexity. Numerous sensors providing many data points make up CPS. Unusual or irregular sensor readings might compromise critically important monitoring and forecasting data. Analysis of the sensed information with multimodal data is crucial for improving system efficiency and human decision-making process.

Technique

In today's world, biosensors can effectively gather data from patients. These sensors may be used in a hospital or at home to gather data about patients, which is then sent to sinks (or microcontroller) and put to use locally or sent to other networks (such as the cloud) via gateways. The sensors might function as nodes in a wide-area wireless network. It is possible to collect data by either passive or active sensing. ECG data, for instance, may be actively sensed, whereas pulse rate can be inferred passively from the former. Therefore, to improve the efficacy of CPS in healthcare, it is necessary to describe the sensing mechanism.

Parameters

The parameter definition is crucial for a successful computational and communication approach. In terms of personal health applications, a system with a single variable may be enough, while a more comprehensive status tracking system might call for a system with many parameters. Pulse rate, oxygenation levels, blood circulation, breathing rate, muscle activity, physical movement, body orientation, and oxygen consumption are just few of the vital signs that may be smoothly monitored by wearable and remote sensors and fed into a multi-parameter system. Assessing health may be difficult due to the diversity sensor metrics present on the basis of systems, measurements, and methodologies.

Data Management

Management of data in medicine CPS offers a plan for handling the information gathered from patients and other sources so that it may be used as intended. Multiple sensors' data must be combined and archived for analysis at a later date. Better data gathering and dissemination are the results of data processing. Raw data from sensors may not be useable due to poor processing and excessive bandwidth requirements. Some notable outliers exist, however. Network-based real-time embedding databases (nRTEDBs) introduced in [8] allow for secure, real-time communication between themselves and wearable network. This database is different from others since it can store unprocessed information. Other features of nRTEDB include the ability to analyze and route data in real time, as well as accurate activity recognition, privacy, and resilience. Three parts make up the data management operation: (i) data consolidation, (ii) data archiving, and (iii) data analysis.

Data consolidation

To gain more insight, the integration of data provides the service meant for gathering data from dispersed sensors. In addition, this reduces the quantity of data that must be sent. When it comes to control and administration of CPS, the sheer amount of sensed data often overwhelms human capabilities. Data merger or assimilation may help bridge the gap between people' purpose of extracting data and their capacity to analyze the obtained information. There are two parts to the data integration process: the combined and the individual. Multiple sensors' readings may be merged into a single set of inputs for analysis via combined data assimilation. Single data assimilation collects and integrates a broad variety of sensor data.

Aggarwal and Xia [9] utilized data on human wellness or activity recognition as an example of sensed data. The sensors may be worn on the body or installed in the surroundings (e.g., on a wall). Interference reduction monitoring for Wireless Body Area Networks (WBANs) was suggested by Ramgoolam and Bassoo [10]. They took use of the fact that cellphones are equipped with both audio output devices (the loudspeakers and the microphones) and input devices (the microphone and the earpiece). Distance between the cellular telephones that serve as the gateways of WBANs is measured using acoustic modelling techniques and Bluetooth module.

Data archiving

Whenever the application layer is mission-critical, e.g., the patient care unit, the information stored within the real-time database must be apt in order to generate data on the status of the framework they portray. Data storage (hub) and dispersed (decentralized) storage and query processing are the two most common methods currently under consideration. The warehousing method involves accumulating information in one location so that it can be queried subsequently. Data in a distributed system is stored and processed locally, with sensors functioning as miniature databases. As a result, there is current work in the field of research to advocate a hybrid model to real-time planning of data, which integrates the best elements of both distributed and storage systems while omitting their drawbacks. In **Fig 3**, we see a high-level diagram of a typical real-time information management architecture. Because sensors' readings are required to accurately reflect the present-moment state of their surroundings, they are susceptible to certain temporal and logical constraints.

Data analysis

It is crucial to process the data correctly for effective computation and communication. Distributed information processing may be carried out either at a local node or on the cloud. Decisions on data processing should be made with consideration for both the specific use case and the available resources. Critical to the success of CPS in medical operations is the timely availability of both the sensor data and the computing power to use it.Data transmission time and information availability update are two aspects to think about while implementing real-time information management for medical CPS. As for data-intensive CPS implementations, Sun, Xiao, Wang and Liu [11]presented a technique to execute regular trade-off between transactional efficiency and data integrity. The suggested technique has significantly wider applicability for CPS compared to previous real-time dataset systems since it does not need keeping all data in main memory.

Computation

The computational tasks in healthcare CPS include (i) monitoring and (ii) modeling. To determine the most effective course of action, CPS for healthcare applications rely heavily on computational model formulation. Physicians and other medical professionals should be able to check up on their patients at any time. The necessary patient information must be readily available to them. By facilitating large-scale, complicated processing and transmission, Cloud Computing facilitates the collection of patient information by biosensors in healthcare facilities and distant observation centers. Some algorithms, such as those for minimizing data bottlenecks and determining data sizes, must be run for the system to function well. In this case, the necessary computing service may be provided using Cloud Computing. High-performance manufacturing, device interoperability, multi-operating model compatibility etc, are all made possible by the cloud.

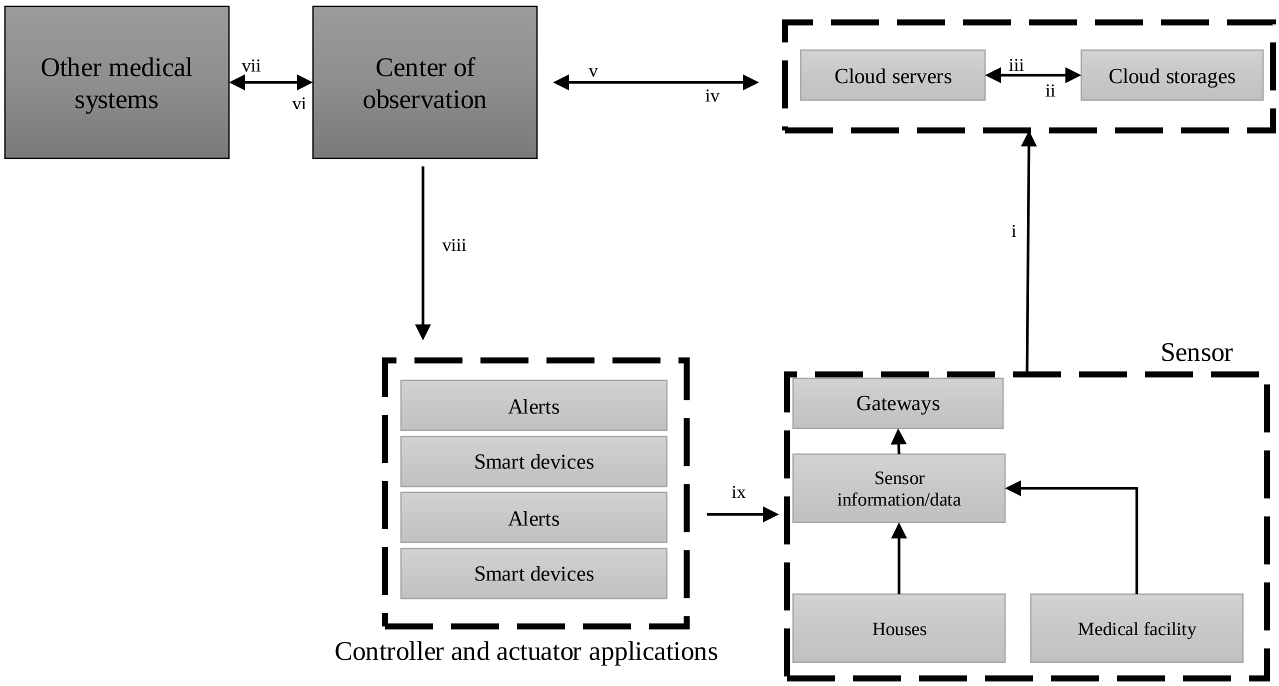

Fig 3. An overview of a generic real-time data management system

Monitoring

In the realm of healthcare, CPSs are used to keep tabs on everyone from newborns to the elderly. The computational complexity is proportional to the amount of oversight. Comparatively, intensive care may require more complex computations than those required for patients in a generally healthy state. The system may need to do some light computing in order to monitor a patient's activities of daily living. Health status monitoring, remote monitoring, and critical care monitoring are all examples of monitoring that may be used in healthcare. A viable telehealth solution was provided by Smolensky et al. [12], which collects patient data for planning at the bedside using a WSN and communicates to the cloud for storage, handling, and dissemination. It was proposed by Pautrel [13] as component of their electronic-Health-MV activities, so it's not an original thought. The authors of [14] design a scheme for emergency medical treatment that makes use of electronic health records stored in the cloud. For emergency medical services, Wang et. al. [15] postulated a cloud-based system that employs palm vein sequence identification system. This information is used by medical professionals who employ a program called digital interferometry and communication systems in medicine to identify their patients.

Modeling

Due to the complexity of the networks and environments involved, CPS design in healthcare necessitates extensive computational resources. Control, communications, feedback, and reaction are only few of the many environmental domains that are often intertwined. Model based calculations are conducted to verify the design. Static or dynamic, these models may be used in a variety of contexts. To create a static model, a user specifies the values to be used in the simulation or the setting in which it will run. In contrast, dynamic models need intricate calculation and design because of their emphasis on prediction and "just in time" methodology. Before putting anything into action, you might get a conceptual sense through model-based calculations. Because of this, the designer is able to refine and optimize the design to greater effect.

Communication

Main communication in a CPS infrastructure for medicine is split between detecting patient data and communicating with the cloud system. Nonetheless, there are subtle exchanges happening across the board, such as between observation centers and healthcare providers. Recent advancements in image communications through WMSN (Wireless Multimedia Sensor Networks) provide the potentials to diversify the potentials of CPS by enabling the transmission of abstracted and condensed images in a resource-conserving manner. This would let doctors keep tabs on their patients more easily and analyze data from images taken of them based on their vital signs. Successful communication requires careful planning and a standard set of rules of engagement. The authors Wang, Claramunt and Wang [16] presented a system approach for the administration and evaluation of massive patient data sets. The most effective method of connecting with a healthcare professional has been investigated.

Scheduling

Scheduling is the method of allocating resources in such a way that communications duties may be carried out to everyone's satisfaction. Task planning, synchronization, and information management may help guarantee that data from biomaterials is sent in real time. There are two main types of scheduling systems: integrated and subscribe/publish. In contrast to the asynchronous nature of subscribe/publish based planning, the synchronised nature of integrated planning is shown here.

Protocol

Certain channels, broadly classified as centralized, decentralized, and hierarchical are used to coordinate the interaction between the sensors. Choosing the right communication protocol is crucial for effective and reliable transmission among the many types of sensors because of their diversity. Problems with the protocol design may arise if just a small amount of data is available from a variety of sensors. Multiple authors, including, e.g., [17], have tried to suggest the connection protocols for complex patient data accessibility during medical service delivery. Nonetheless, the issue remains owing to the diversity of data sources, therefore further investigation is required.

Security

Since patient information must be kept private for both legal and ethical reasons, data security is of paramount importance. Therefore, it is crucial to give careful consideration to data security throughout the design phase of a CPS design for medical applications. There are two parts to every secure system: (i) encoding data and (ii) keeping information private.

Encryption

The interactions between the various users and healthcare professionals in this medical care application must be protected. Encrypting sensitive information is one way to prevent unauthorized access. Depending on the kind of application and the desired degree of security, data encryption may be handled either by the user or by the network. Whilst cloud computing services are guarded by security mechanisms, encryption of the information at user level gives superior protection. ABE, or attribute-based cryptography, can be used to secure sensitive information. Any authorized staff may decrypt the data using a private key. Security is particularly important when dealing with personal health information in the public cloud since the supplier is a third party. Disclosed patient information might lead to legal and ethical complications. In addition, systems for spotting data corruption and illegal access may be put in place.

Privacy

Experts in the healthcare sector are required to uphold patient-doctor confidentiality and data privacy standards. Sensors, services, and individual patient data available in the medical industry are constantly growing. The framework configuration's inability to respond to unanticipated future situations makes handling all of these a challenge. Thus, protecting confidentiality of information is crucial both at the database and application levels. Because of the large number of users and clinicians implicated in medical applications, it is crucial that all communications between them be encrypted. While encryption on the server side is helpful, encrypting data at the user level is even more secure. Unauthorized entry and information corruption can be detected through the use of deployable mechanisms. The centralized command authority at the observation center is thought to be impregnable by an enemy. The assault may be detected by the base station using a failed verification of anonymity technique. To assure the safety of wireless WBAN, Ali and Khan [18] adopted biometrics. There are two levels at which data privacy may be ensured: the application level and the data level. The degree to which an application may choose which data to keep private varies.

Controller/Actuator

The ability of today's healthcare systems to recognize critical patient information and immediately notify the appropriate healthcare provider is severely lacking. Today, most warning systems are set up with a threshold alarm. When a vital indicator exceeds a certain limit, a threshold alarm is triggered. Each controller/actuator consists of two parts: (i) the mechanism, and (ii) the decision-making circuitry.

Mechanism

The controller/actuator framework can be either automatic or manual depending on the requirements of the application. Given that CPS is a system that includes computing, information exchange, and physical agencies with an emphasis on their interactions, understanding the mechanisms underlying CPS is crucial. In order to analyze the overall system's performance, it's important to have a mechanism in place for doing so. The mechanism specifies whether the system's responses is predetermined or left up to the discretion of the user, thus addressing a key issue in the development of real-time medical care applications. In healthcare, there have been numerous attempts made to enhance the precision of threshold alarms. However, each solution requires a unique gadget. Independent threshold alarm systems have high rates of alarm generation, which amounts to false alarms. Practitioner burnout is a common result of false alarms. A strategy for the stable integration of heterogeneous data sources is required because CPS in the medical scenario will take into account various sensor types. To improve the viability of CPS, Subba, Biswas and Karmakar [19] proposed a battleground-informed approach called Tru-Alarm. When evaluating a patient's condition based on collected data from a variety of sensors, reputability assessment can be an invaluable resource for determining which measurements to trust.

Decision-making circuitry

Due to the potentially life-saving nature of medical data, it must be made available to licensed medical professionals at all times and in any location. Also, healthcare applications need a lot of computing power so that doctors can make educated decisions based on patients' extensive medical records. The ability of today's healthcare systems to recognize critical patient information and immediately notify the appropriate healthcare provider is severely lacking. Currently, threshold alarm is the most common setting for an alert system. When a vital sign exceeds a predetermined limit, a threshold alarm is triggered. A threshold alarm can reliably alert you to a dangerous situation in a flash. However, because of the frequent false alarms caused by this strategy, caregivers may become overwhelmed and choose to ignore or disable the alarms altogether. The standard of healthcare provided is known to suffer as a result of this. Therefore, it is crucial to employ a method that will lessen the number of unwarranted alerts.

V. CLASSIFICATION-BASED MAPPING OF MEDICAL CPS

In this subsection, we use the classification introduced in the preceding subsection to categorize the CPS suggested so far for use in healthcare. This description (or projection) aims to assist in visualising how different CPS suggested for healthcare applications combine physical and virtual abilities through applications, infrastructure, monitoring, information management, computing, communications, privacy, and controller/actuator.

Prominent CPS Applications

Electronic Medical Record (EMR) relates to the procedure of developing a cyber-physical connection to acquire objective measurements of health status. The conventional method of interpreting pulse rate, which is time-consuming and error-prone, will be replaced by this method. With this cyber-physical interface architecture for linking sensors via a wired connection, an EMR structure may collect and store standardized data. This prototype is comprised of an EMR, an information handler (a computer adapter), a pulse rate reading stations (hardware architecture), and a customized vital signs application. This SDD dissects the cyber-physical method down to its structural pieces and describes the architecture in great depth. The design's levels are self-contained entities that do not depend on any higher-level layers for their operation. The primary benefit of this approach is that it permits independent changes to individual elements, which in turn benefits the system as a whole. The data level is in charge of regulating user accessibility to the database, the applications logic layer processes user requests, and the interface level displays the results to the user. Notable CPS uses are listed in **Table 2**.

Table 2. Application cases for CPS

Application	Details
EMR	EMRare the result of efforts to create a cyber-physical connection for the automatic collection of vital signs. Reading vital signs manually is a time-consuming process prone to mistake. This cyber-physical interface architecture is meant to facilitate the integration of sensors across a wired network, with the ultimate goal of accessing and storing data as structural information inside an EMR system. Data Dispatcher (Application Adapter), Electronic Medical Record, Vital Signs Learning Depot (Device Topology), and Personalized Vital Signs Form are all components of this design. This SDD is a discussion and breakdown of the cyber-physical strategy into its component parts using a three-tiered architecture. The elements in this infrastructure are organized into layers, each of which is decoupled from the ones above and below it. The primary benefit of this method is that it allows for the modification of individual components without affecting those in higher-level layers. The data layer intercepts interconnection to the datasets, the application inference layer implements the business line of thought, and the interface stack includes the elements requisite for observing the application.
CPeSC3.	Communication core, data processing core, and resource planning and managerial staff core are the three main pillars of the CPeSC3 architecture reviewed by Salo [20]. The authors conduct an in-depth examination of pertinent models, including those that underpin Cloud Computing, security, and real-time scheduling. In this paper, we display a medical application situation for validation purposes, based on an actual test bed. The authors used Cloud Computing to improve healthcare delivery. Nevertheless, the suggested scheme does not account for the nuances of sensing data. Complete system consistency is essential for any CPS used in healthcare, but CPeSC3 doesn't emphasize that. Despite making some attempts to address the shortcomings of CPeSC3, Haber and Schneidman [21] did not suggest a fully functional CPS architectural features. This gap can be filled in by further study.

CYPSec.	Conventional security components and environmental elements are combined in the cyber-physical security (CYPSec) approach presented by Wang and Yan [22]. The authors provide two concrete examples of this general approach to demonstrate the design challenges and principles of CYPSec: For example, (i) PhysiologicalSignal-oriented Key Agreements (PSKA), and (ii) Criticality-Aware Accessibility Controls (CAAC). PSKA is planned to provide automatic shared key among devices in the wireless communication system associated with physiological indications from the body, with CAAC having the control of activating the network for disaster response.
Cyber-Physical WBAN Systemsbased on Social Networking	Based on data collected from people's social interactions, Wang, Sun and Ji [23] developed a power game-based solution to reducing communications disruptions in WBANs. The authors made contributions in the following aspects: (i) designing the inter-WBAN interventions and establishing the range allotment of intervention based on theoretical study and Numerical Simulations; (ii) creating social communication identification and modeling techniques for people holding WBANs; and (iii) creating a power control game depending on the social communication data in order to increase the program's functionality while decreasing energy usage of WBANs. The authors also provided the power boost and price variables, and they claimed to have shown the presence of the Equilibria in the games of power management.
Big Data Platform and Medical CPS (MCPS)	For medical decision making, Geseleva and Yaroslavtseva [24] suggested a big data analytical infrastructure for medical CPS, which incorporates the 'real' domain, with the 'virtual' and 'elastic' elements. The authors assert that their methodology can cut down on unnecessary medical spending and make regular patient checks less of a burden on doctors. Sensors are attached to the patient in a distant healthcare surveillance system in order to collect data on the patients' vital signs, e.g., oxygen levels, electrocardiogram (ECG), and heart rate. Doctors may then use this information to assess patient health by accessing it from a distant database server.
Smart Checklist.	As a means of assisting and directing human participants in activities, Mhaisen and Malluhi [25] presented a smart checklist. The system also allows users to communicate with and communicate with their gadgets and programs. It is anticipated that this technology will aid the medical personnel in critical care with drug preparation, data collecting, and other mundane but necessary tasks for their patients. The authors have created a comprehensive system design, infrastructure, performance monitoring, contextual understanding facilities, time-based and profile-based assessment, and security envelops. However, at the present time, not all medical procedures can benefit from this system.

VI. CONCLUSION

In recent years, Cyber-Physical Systems (CPS) have garnered a lot of attention as a potentially fruitful new area of study. As such, it bridges the gap between the virtual and the tangible. In 2009, CPS was considered the top study priority by the United States National Advisory Committee of Advisors on Technology and Science, following its selection as an NSF priority field of study in 2008. CPS features such as sensing, handling, and connectivity. New advancements in Wireless Sensor Networks (WSNs), clinical detectors, and cloud services have made CPS a realistic choice for application in a wide range of medical configurations, including in-patient and out-of-hospital care. These advancements hold the promise of allowing CPS to track patients remotely and respond appropriately regardless of their location. Extensive study has been conducted on healthcare sensors. These sensors can be used to collect vital information about patients, such as medical history. The information is sent wirelessly to a central hub. However, wired detectors could still be used in certain circumstances, despite the fact that wireless sensors offer additional comfortability for both healthcare workers and patients. Once the sensor data is saved to a server, it may be accessible by medical practitioners. Keeping patient data safe is of the utmost importance because it is shielded from declassification by law and professional ethics. This highlights the importance of prioritizing data security when designing a CPS infrastructure for medical care applications. Many medical sensors generate vast amounts of data, creating a need for secure, efficient methods of storing and managing that information. In this light, reliable and efficient database management tools are crucial. Given that a patient's medical history has the potential to reveal the intervention (therapies) required to extend their life, it is crucial that this history be made instantly accessible and available to licensed healthcare professionals at any time and at any location. Applications used in healthcare likewise need a lot of computing power in order to handle the massive amounts of patient data necessary to draw meaningful conclusions. Energy usage, processor power, and storage capabilities are all severely limited in networks of remote monitoring that gather patient data. CPS in medicine have been reviewed in this work. To help with this, a quick introduction to CPS will be given. Next, we propose a classification that characterizes CPS for medical applications from many vantage points (components), including but not limited to: application, infrastructure, sensing, information management, computing, communications, security, and controller/actuator. This categorization is useful for illustrating the developments, methods, and possible CPS approaches around certain uses. Healthcare initiatives that make exclusive use of Cloud Computing and WSN have also been mapped to the classification for CPS initiatives.

Data Availability
No data was used to support this study.

Conflicts of Interests
The author(s) declare(s) that they have no conflicts of interest.

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Competing Interests
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