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RESEARCH ARTICLE

CYBER PHYSICAL SYSTEMS FOR HEALTHCARE.

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Abstract

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In the modern world, Cyber Physical Systems (CPS) can be considered as a new generation of systems with integrated control, communication and computational capabilities. Just as the Internet has transformed, how people interact with each other, cyber physical systems will transform the interaction of people with the physical world. Currently, the study of CPS is still in its infancy and there exist many research issues and challenges ranging from electricity power, health care, transportation and smart building, agriculture etc. In this article introduces the architecture of CPS (cyber physical systems and wireless sensor networks (WSNs) for cloud computing for life support or healthcare) and its application for monitoring and decision support systems. The proposed CPS architecture consists of three main components: 1) the communication part, 2) the computation part, and 3) the resource management part for healthcare. Such integration, which is called Cyber-physical Systems (CPS), is transforming the industry, agriculture and hospital into the next level. CPS facilitates the systematic transformation of massive data into information, which makes the invisible patterns of degradations and inefficiencies visible and yields to optimal decision making system. This paper focuses on existing trends in the development of hospital big data analytics and CPS.

Detailed analysis and explanation are given for relevant models such as cloud computing, real time scheduling and security models. Finally, a health care application part is presented based on our practical test bed which has been built for several years. With the rapid advancement of Information and Communication Technologies (ICT) and the integration of advanced analytics into manufacturing, products and services, many industries and hospitals are facing new opportunities and at the same time challenges of maintaining their competency and present needs. Finally, a case study on the development of intelligent machines using the CPS is presented.

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Introduction:-

Last year decades, manufacturers and service providers have made a significant step towards improving the quality of products and services and optimizing their processes in order to maintain their competence and meet market requirements [1]. This evolution has led to the development of the better solution for Health and Management. Health and Management solutions can transform data into the right information and knowledge about invisible models of asset degradation, as well as inconsistency and inefficiency of the processes [2].

Struggle the inherent problems of developing Health and Management for complex mechanisms and processes have expanded significantly and contributed to the development of intelligent maintenance systems. In the past few years, the rapid development of information and communication technologies (ICT) has facilitated the implementation of radio frequency identification (RFID), advanced sensors, Zigbee technology, data collection equipment, wireless communication devices and solutions for remote computing. Such technologies, along with advances in prediction analytics, change the face of modern healthcare or hospital. Integration of advanced analytics with communication technologies in close interaction with physical equipment has been called cyber physical systems (CPS) [3].

From the beginning of its concept, CPS has been the ubiquitous terminology in the modern developing industry, healthcare and agriculture, and so on. It deals with the integration of physical systems with computational models. Such a scheme has a wide range of applications, including process control, energy, transport, medical devices, military equipment, automation, intellectual structures, etc [2]. Currently, the CPS concept is still under development. In the area of information Systems Management (ISP), CPS has the potential to provide self-awareness and self-maintenance capabilities. The implementation of analytical analytics as part of the CPS framework enables the assets to continuously track their own performance and health status and predict potential failures. By implementing this analytical system along with a decision support system, proper services could be requested and actions taken to maximize the uptime, secure and efficiency way observe of the healthcare or hospital systems. CPS, as the central hub for data management or Information System Management (ISM) in fleet level, plays a critical role in achieving the above mentioned goals. The principal goal of this paper is to use CPS for the Internet of Things (IoT) and Communication technologies to design a low cost system for combating the Medical Health and thus reducing both the mortality rate and the financial burden.

Motivation CPS

In the Modern World, Information and Communication Technologies (ICT) get increasingly integrated and embedded into our everyday environment. With becoming connected and intelligent, today's embedded systems evolve to cyber-physical systems. Embedded ICT - from components to cyber-physical systems (CPS) - gain in importance more than ever, not only for the ICT supply industry but also for all major mainstream sectors of the economy. This represents a great opportunity for innovators and industry in Modern World. In fact, in Modern Countries main strengths is the capacity to build safe, secure, reliable, small size, low power and real time responsive embedded ICT systems [31].

In future, embedded ICT will become mainstream: The core ICT devices that were so far confined to boxes (PCs, smart phones, tablets, etc..) are more and more embedded in all types of artefacts making "smarter" our homes, offices, factories, cars, trains, public spaces, cities and also our clothes. These are also increasingly connected to the Internet making the "Internet of Things" the "Internet of Everything": of individuals, communities, and all types of smart artefacts (including sensors, actuators and robots).

Maximizing the value from the move to a "smart everywhere society" will depend on our capacity to accelerate the integration of electronic components, smart integrated systems and embedded software in all types of products and services. The wider embedding of ICT in products and artefacts will have a major impact on uplifting Modern Countries innovation capacity across the economy from traditional industrial and professional service sectors to emerging consumer sectors.

Right now, the modern World stakeholders are working on their Research and Innovation strategy for electronic components and systems, of which CPS are an integral part. CPS and its enablers are key topics under the ICT part of the Horizon 2020 pillar on Leadership in Enabling and Industrial Technologies.

Internet of Things

Identification and tracking technologies such as the Radio Frequency Identification (RFID), Barcodes and Near Field Communication (NFC) have enabled humans to interact with daily things and service machines, and have allowed objects to interact with each other. Nanotechnology, ubiquitous Wireless Sensor Networks (WSNs), attached and embedded sensors and tags have given the ability to connect to physical objects. These technologies have enabled monitoring and gathering data about animals, machines, difficult access areas, whether and human vital signs.

Previous technologies in addition to communication technologies, such as Bluetooth technology, Wi-Fi, ZigBee and smart devices such as smart phones, tablets, and robotics brought new services which formed together with the current Network services the foundation of the Internet of Things (IoT) growing. Such platform brings about the capability of implementing big data predictive analytics for transformation of data to information to knowledge to action through a CPS structure.

In the few coming years, the rapid growth of these technologies will contribute to narrowing the gap between physical and digital world at typical speed. In this paper, many (IoT) technologies have been highlighted, their features and functioning methods were clarified and interrelations with each other have been analyzed [4].
Figure 1 provides an schematic view of how big data analytics can create value within different sections of industries. In the next section, the structure of CPS along with its implementation aspects is discussed.

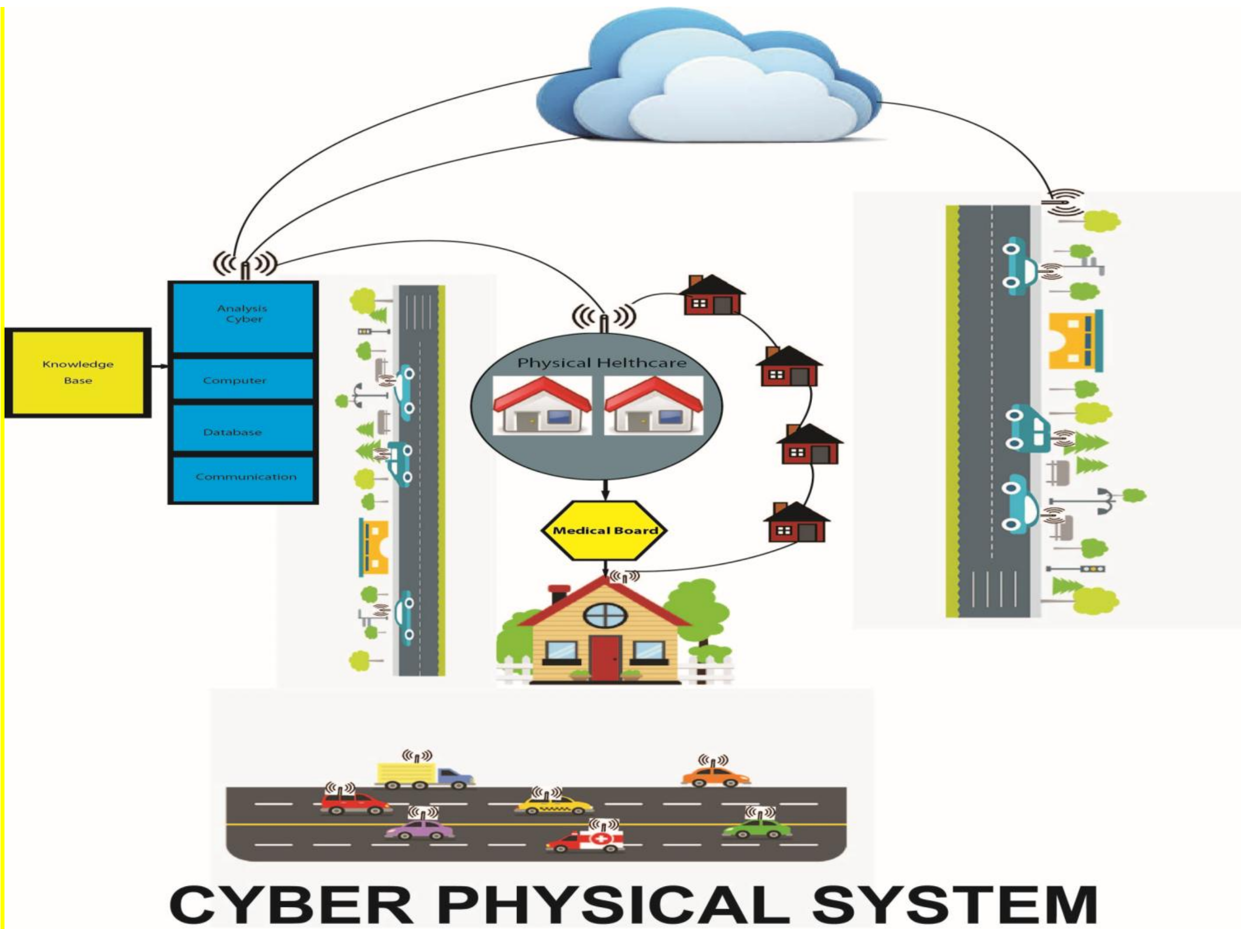


Fig.1:-Cyber Physical Systems for Healthcare

Cyber Physical Systems For Healthcare (CPSsH)

With the rapid transformation of various medical systems, there is a strong requirement for new devices with increased functionalities. The term of Medical Cyber Physical systems refers to systems that have a combination of embedded devices, software for controlling these devices and communication channel for interaction. For developing safe and effective CPSH requires new design, verification and evaluation techniques due to increase in size and complexity.And the challenges for developing these kinds of systems include executable clinical workflow, model based development, physiological close loop control, adaptive patient specific algorithms, smart alarms and user centered design and infrastructure for medical integration and interoperations. The application scenario for **CPSsH** varies from patient monitoring, analgesic infusion pumps to implant sensor devices.Cyber physical, medical system modeling and analysis is a framework proposed for safety verification of different applications. The scenario considered in the experiment was analgesic infusion pump control algorithm for keeping the drug concentration in the blood to a fixed level. These systems are example for typical closed loop systems. Any change in the physical world can directly enhance it in the cyber world and an action will be taken at the physical world based on the instruction given from the cyberspace [5].

The CPS structure provides a guideline for the development of CPS for industrial applications or hospital. This CPS structure consists of two main components: 1) the physical space and 2) the cyberspace [17]. The proposed structure provides a workflow in Figure.2 that shows how to construct a CPS system from the data acquisition to value creation. The framework or architecture of CPS in different levels is shown in Figure.3. The structure consists of Smart Connection, Data to info Conversion, Cyber, Cognition and Communication levels. All the part will be worked step by step communication like as a cycle.

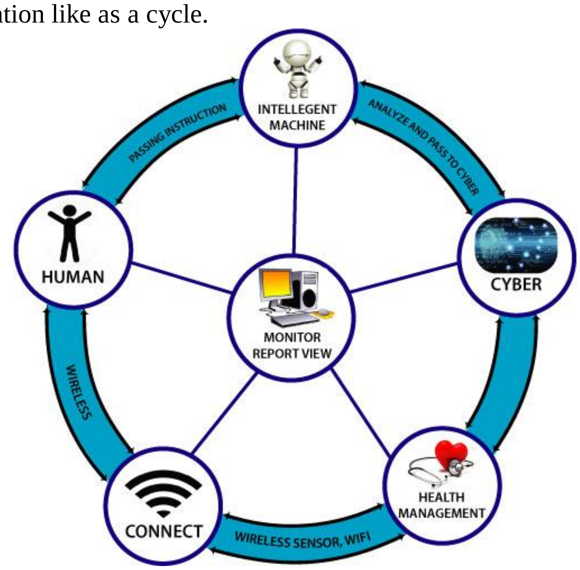


Fig.2:-CPS workflow cycle

Sensors

Internet of Things (IoT) includes a large number of applications, which basically depend on sensors; practical applications vary from taking simple measurements done by one sensor to half complex applications such as: smart home automation up to highly complex systems as smart grid. As IoT is growing quickly the number of needed sensors is growing accordingly and it may arrive to 45 trillion in the next 20 years.

Sensing is a vital need for both artificial and human related applications for allowing the interactivity with the surrounding in intelligent ways. Users can interact with a large size of information without the need to be conscious of it. Sensors are tiny electronic devices which are considered the foundation stone of IoT. They are made of sensitive materials and have the ability to sense and measure changes of physical parameters (measurable quantities) and convert the captured signals into analog or digital values. Sensors can cooperatively gather and transmit data to sensor nodes through wires or wirelessly. In future Internet, including the IoT intelligent algorithms and the cognitive capabilities into sensors will enable them to act as intelligent objects not just as sensors [8].

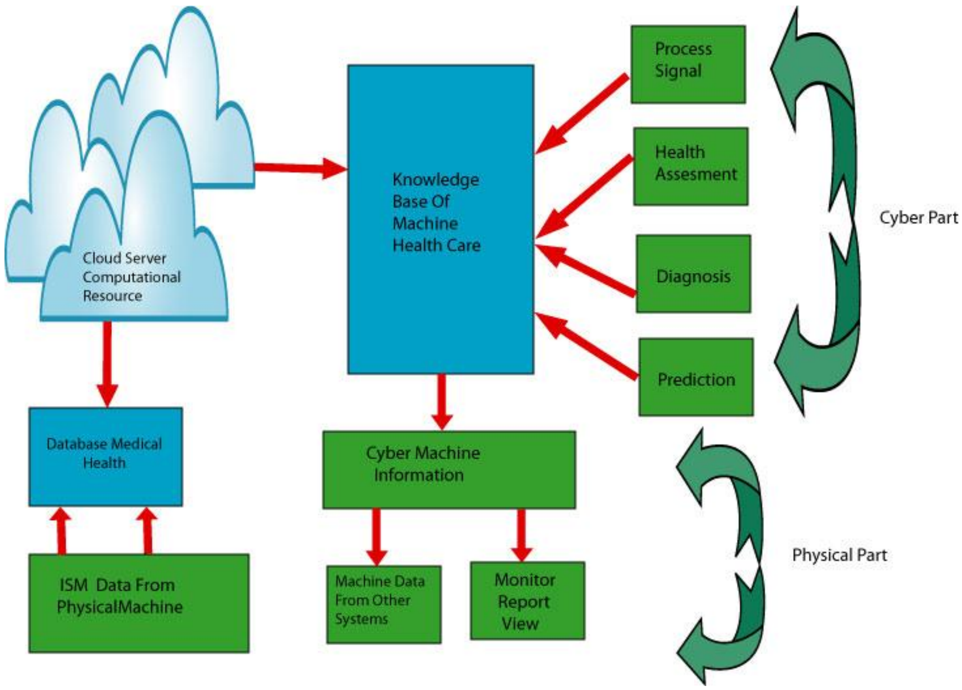


Fig.3:-CPS Architecture

Wireless Sensor Networks (WSN)

Wireless Sensor networks occupy a decent position and play a major role in IoT deployment. They contribute providing a better monitoring and tracking of the daily objects and thus wider awareness of the surrounding. WSNs are easy to use that sensors can be deployed anywhere, and they have the feature of speed setting that WSNs can be installed in few hours. WSNs are adaptable with the hard environments that a large number of WSNs can work independently of the Internet and sensor nodes have features of flexibility, heterogeneity, and mobility. Nowadays, several kinds of WSNs are used in a variety of domains such as environment, agriculture, structure and healthcare.

A number of low power, low cost, easy to use, inexpensive and disseminated sensor nodes are connected to each other via wireless communication and in a wireless multi-hope way to form a WSN which has an ever-present nature. The sensor node sends a site reference to the main server ISM which in turn locates the region of occurred changes [16]. Some applications allow users to get information about the temperature by using their smart phones to interact with dedicated sensor nodes placed in their region. WSNs were firstly used in military applications, but due to the ease of sensor's dissemination WSNs started to be used in other domains such as fire detection, machine wellbeing monitoring, intelligent homes, irrigation systems, intelligent transportation systems, E-health, and telematics.

RFID Technology

RFID as one of vital IoT technologies is based on radio waves to build the communication between RFID readers and RFID tags. The main goal of RFID is to identify and track the everyday objects in addition to monitoring the environmental variables by means of attached tags. RFID technology was firstly used in military applications in the forties of the last century. Low-cost RFID TAGS manufacturing appeared in the last decade of the twentieth century. Each RFID tag consists of a small integrated circuit (IC) for storing and processing data, modulating and demodulating the (Radio Frequency) RF signal. The IC is connected to an antenna which is used for receiving and sending the RF signals [15].

RFID tags can store a little amount of data about the monitored object, in addition to small size applications and they can be attached to daily things to provide them with interactive capabilities. RFID technology marks daily life objects with unique identification numbers, so it facilitates the communication with those objects and thus contributes to spreading the IoT. RFID tags are either passive or active; passive tags do not have power sources, are very cheap, and can survive and keep readable for a long time. RFID passive tags can operate at all radio frequencies, but active tags operate only at higher radio frequencies.

Intelligent connection

This level consists of seamless and problem-free methods of managing data collection systems, optimizing and transferring data to a central server. Choosing the right sensors, data sources and transferring protocols at this level can have a significant impact on CPS performance at the following levels, as well as on the quality and accuracy of the knowledge found in the system [6].

Data to information conversion

The core of this architecture is where data are analyzed and transformed into valuable knowledge. Recently, the main attention is paid to the development of intelligent algorithms and methods of data mining. Such algorithms can be applied to various data sources: from machines and process data to business and enterprise management data [14].

Cyber

The cyber-level acts as the central information center in this ISM database. The information is extracted from each source and compiled to install cyberspace. Having huge information, a certain analyst is used to extract additional information that provides a better idea of the status of individual cars in the park.

Cognitive Device

The introduction of CPS at this level gives a complete knowledge of the controlled system. Correct presentation of the acquired knowledge to expert users confirms the correct decision to be taken.

Knowledge Base

The core of this architecture is where data are analyzed and transformed into valuable knowledge. Recently, the main attention is paid to the development of intelligent algorithms and methods.

Such algorithms can be applied to various data sources: from machines and process data to healthcare and Information System management data [11].

System Configuration

The configuration level is the feedback from cyberspace to physical space and acts as a control check to make the machines self-tuning and self-adaptive. This stage acts as a stability control system to apply corrective and preventive solutions that were made at the cognitive level of the controlled system.

Intelligent Machine

Processing processes in the manufacturing industry represent a very dynamic and complex situation for the management of healthcare information systems management (ISM). A computer numerical control (CNC) can usually process a wide range of materials with different hardness and geometric shapes, and therefore requires different combinations of machine parameters for work. Traditional ISM strategies are usually developed for a limited range of machine types and operating conditions and therefore cannot be used to efficiently process the entire production floor where machines can be used in a wide range of operating modes that cannot be pre-modeled in advance. As a result, the CPS structure with the proposed CPS structure is developed for the sawing processes. The developed CPS for machine tools can be used to process and analyze processing data, assess the health status of critical components and further improve the overall efficiency and reliability of the equipment by predicting upcoming failures, scheduling pre-service and adaptive management. In such a situation, the health of the band saw and its components play a significant role in both speed and cuts. Thus, the availability of accurate health information from the machine will provide significant assistance in maintaining speed and precision of cutting [9].

As shown in Figure.5, at the connection part, the data are taken from the machines using both additional sensors and controller signals. In addition to the additional vibration, acoustic emission, temperature and current sensorst are output from the controller to provide a clear view of the operational status of each machine. The data are now processed on an intelligent computer connected to each machine. In the conversion level, the intelligent computer further performs feature extraction and data preparation. The feature extraction consists of extracting conventional time domain and frequency domain features such as kurtosis, frequency band energy percentage, etc. from vibration and acoustic signals. Calculated features along with other machine state data is being sent through Ethernet or Wi-Fi network to the cloud server where the feature values are managed and stored in the database [10].

In the cyber part, cloud server performs an adaptive clustering method to segment the blade performance history into discrete working regimes based on the relative change of the features comparing to the normal baseline and the local noise distribution (figure.5). The adaptive clustering method compares current values of the features with the baseline and historical working regimes. It identifies the most suitable cluster from the history to match with the current working condition. If none is found, the algorithm generates a new cluster as a new working regime and generates related health models for that regime. Further, if the same working condition happens, the algorithm has its signatures in memory and will automatically cluster the new data into that specific working regime [7].

Health stages can be additionally used at the cognitive level and configuration level for optimization purposes. To help in this decision, user interfaces based on the Web and iOS have also been developed so that access to information about the health of each connected machine can be obtained in real time (Figure.4).

Information System Management (ISM) Database

A database is any collection of data organized for storage, accessibility, and retrieval. There are different types of databases, but the type most commonly used in healthcare is the online transaction processing database. In our discussion, a healthcare database serves to replace the paper documents, file folders, and filing cabinets of old. The data is now more convenient and immediate. An online transaction processing database is one that a single computer application runs on. An electronic health record is a prime example of such an application. The main strength of an Online Transaction Processing database is that it allows for quick, real-time transactional processing. It is built for speed and delivers sub-second response times. For example, when a patient presents at the front desk, you search for her name in the electronic health record and instantly see a result. Likewise, you enter her blood pressure into the electronic health record and the information is instantly stored there.

Comparison of Conventional sensor and IoT Sensor / Embedded Sensor/Smart Sensor

Conventional Sensor (CS)	**IoT Sensor**	Reference
CS solutions contain a linear communication channel between various machines that enables them to form a work cycle. It's more of a cause and effect relation where one action triggers the other machinery into activity.	IoT can be defined as a system where multiple devices communicate with each other through sensors and digital connectivity. They talk to each other, work in tandem, and form a combined network of services.	https://arxiv.org/pdf/1802.02041.pdf, arXiv:1802.02041v1 [cs.CR] 6 Feb 2018
CS refers to communication and interaction between machines & devices	IoT has broader scope than CS, since it comprises broader range of interactions, including interactions between devices /things, things and people, things with applications and people with applications. It also enables composition of workflows comprising all of the above interactions	https://www.talend.com/blog/2016/12/08/sensors-environment-and-internet-of-things-iot/
CS solutions operate by triggering responses based on an action. It's mainly a one-way communication.	The key advantage IoT has over CS solutions is the ability to add interactivity amongst devices. In this system to and fro communication flows freely. There can be countless scenarios and combinations.	https://arxiv.org/pdf/1802.02041.pdf, arXiv:1802.02041v1 [cs.CR] 6 Feb 2018
CS solutions rely primarily on conventional connection tools like wired connection , in wireless wifi, cellular, Bluetooth or Radio etc	IoT adds more sophisticated sensors into the mix. its result, Internet of Things based systems have much more flexible and varied connectivity options.	https://arxiv.org/pdf/1802.02041.pdf, arXiv:1802.02041v1 [cs.CR] 6 Feb 2018
CS solutions, because of their limited scope, are confined to creating a network of machines that work in synchronization.	On the other hand, IoT creates 360° solutions that allow for flexible responses and multi-level communication.	https://arxiv.org/pdf/1802.02041.pdf, arXiv:1802.02041v1 [cs.CR] 6 Feb 2018
CS device in the field on IP (GPRS, UMTS, HSPA and LTE) is connected to the Internet, and for the connection to the Internet we all know different options (SMS by GSM modem and CSD by analogue modem and ISDN modem). In IoT everything is different.	A big part of the IoT will be on IP. IoT will not be on IP only gateways also. The European protocol M-Bus gets wired and wireless. This popular protocol is non IP. If we would like to connect the metering world, then a gateway is a must [13].	Harald Naumann, Author of the IoT / M2M Cookbook http://www.gsm-modem.de/M2M/m2m_iot_cookbook/

		Updated Feb 17, 2014
It started with CS when devices became smart and were able to connect to other devices via cellular networks and send data. This was Conventional Sensor.	Evolution continued and **IOT** set in. Now devices now leveraged an architectural framework which allows integration and data exchange between the physical world and computer systems over existing network infrastructures [12].	http://zone.ni.com/devzone/cda/pub/p/id/1523metc=mt4psm
Point to point communication usually embedded within hardware at the customer site.	Devices communicate using IP networks. Incorporating with varying communication protocols	http://zone.ni.com/devzone/cda/pub/p/id/1523metc=mt4psm
Many devices use cellular or wired networks.	Data delivery is relayed through a middle layer hosted in the cloud.	http://zone.ni.com/devzone/cda/pub/p/id/1523metc=mt4psm
Devices do not necessarily rely on an internet connection.	In the majority of cases, devices require an active internet connection.	http://zone.ni.com/devzone/cda/pub/p/id/1523metc=mt4psm
Limited integration options, as devices must have corresponding communication standards	Unlimited integration options, but requires a solution that can manage all of the communications.	http://zone.ni.com/devzone/cda/pub/p/id/1523metc=mt4psm

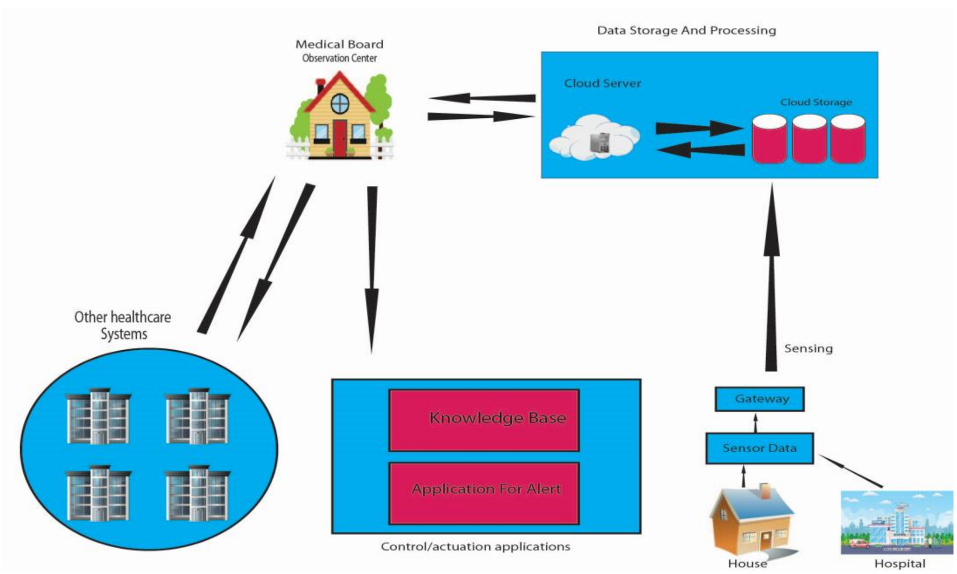
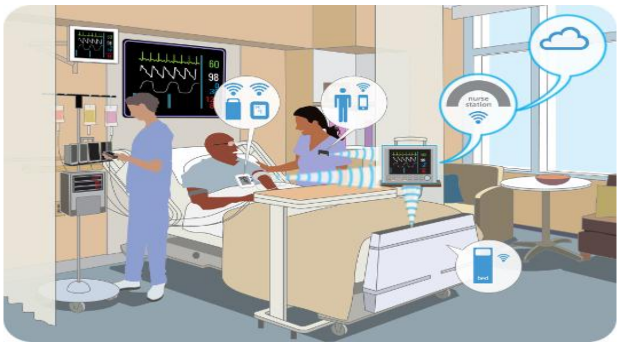


Fig.4:-Overall CPS setup for self-adjustable for Healthcare

Wearable Tech

Smart Appliances



Healthcare

Fig.5:-IoT base access to machine health information

The **Internet of Things** (**IoT**) is the network of physical objects - devices, vehicles, buildings and other items embedded with electronics, software, sensors, and network connectivity that enables these objects to collect and exchange data in Figure.5.

Conclusion:-

This article discussed current trends in the implementation of cyber physical systems in the manufacturing industry. Since the management of industrial large data has become a challenge for enterprises, it is necessary to develop a common architecture for implementing CPS in production. The architecture of CPS, which is discussed in this article, is capable of automating and centralizing data processing, health assessment and prognostication. This architecture covers all the necessary steps for acquiring data, processing information, presenting to users and supporting decision-making. In addition, the health information generated by the system can be used for higher-level functions such as maintenance scheduling and optimized management to achieve higher overall system performance and reliability. The architectural features of CPS are briefly demonstrated in the study of CNC machines. The case study shows the integration of CPS architecture for processing and managing a fleet of CNC machines that are commonly used in production.

Future work: In the field of cyber physical systems (CPS) focusing on the health care industry where computational intelligence is used for decision support. We will analyze the present state of the art and trends in cyber physical system in the healthcare, industry and summarize the issues of communication part that need to be overcome. We conclude by identifying the future challenges in this technology that needs to be addressed in order to identify and facilitate priority research in this emerging field.

The current integration of the architecture of the CPS is at an early stage, so advancement in all levels of the architecture is practical. The cyber level, in particular, has great potential for advancement, developing new algorithms for analyzing the power level of machines using distributed data management systems.

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