



# INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

## AI Enabled Internet of Medical Things

*Kishalay Raj<sup>1</sup>*

<sup>1</sup>*Kishalay Raj*

*BIT Mesra, Ranchi, India*

### Abstract

AI Enabled Internet of Medical Things (AIEIOMT) are playing a very crucial character in medical industry to increase exactness, productivity, and reliability of the electronics instruments. Recent advances and development in conceptual and design science, Technology and connectivity have led to the emergence of Artificial Intelligence and Internet of Things (IoT) applications in many industries and with an emerging field with great development outlet potential in future years. Nowadays scientists are focusing to establish a digital-physical healthcare system by the interconnections of available medical resources, various healthcare services and digitally smart devices. This paper studies the impact of Technologies such as IoT and AI in healthcare. This analysis further reveals that the application of these technologies in disease diagnosis, forecasting, detection, and treatment, wearables and connectivity, patient care, sensor networks, identified gaps and future research directions related to technical design, acceptance, regulations for data security and privacy and systems efficacy and safety. The relevant impact factors in the blueprint and development of magnified healthcare systems are the related Research fields Artificial intelligence (AI), Big Data (BD), and Internet of Things (IoT). In the paper the concentration is focused on AI in IoT and healthcare system, which includes utilization and execution of AI methodologies many disciplines of healthcare. This paper work exhibits the principal areas of AI methodology in disease detection, prediction, medicine, robotic surgery, and personalized treatment. Furthermore AIEIOMT addresses numerous health conditions like diabetes, activated parameters of biophysical supervisions along with subsistence system in decision making. As IoT has various converging domain but our focusing domain is the contribution of IOT in healthcare fields.

The Internet of Medical Things has convergence with several domains but our research contribution correlated to AI and IoT in healthcare, previous contribution, ultra-modern contributions in Covid19 Epidemic, Opportunities, applications and subsequent challenges in terms of medical services in healthcare industry.

AI Enabled Internet of Medical Things depute the medically interconnected communication devices and their integration in health network towards patient's health improvement. Even so, due to critical behavior of health-related systems, AIEIOMT still facing various challenges specially in terms of security, safety and reliability.

In this literature we represent the comprehensive scientific research, new contributions in order to improve AIEIOMT by the usage of traditional methodologies furnished by cyber-physical systems. We outline remarkable experimental and realistic applications of standardization of medical devices for

patient itself, guardians of patient, doctors, nurses and healthy people too. We also try to recognize Unexposed research oriented direction and trending potentials to solve uncharted research complications.

**Index Term** :- Artificial Intelligence (AI), Internet of Things (IoT), Medical System, Healthcare, Opportunities, Challenges,

### **Introduction**

Basically, IoT is termed as permeative and persistent internetworking of electronic devices to enable data transfer and communicate between domain specified applications of these devices and the surrounding. Due to this reason internetworking of IoT has made human life much easier than earlier. It is used in numerous fields like pharmacy, farming, monitoring of indoor quality, pollution management, and many additional usages to enhance lifestyle environment and upgrade well-being. The most pertinent application of IoT can be seen in the medical field where it has led to the creation of up to date paragon known as AI enabled Internet of Medical Things (AIEIOMT). AIEIOMT offers various contingencies such as wearable sensors are commonly being used by people for enhanced health and prosperity intimately correlated with mHealth and eHealth.

Its availability, low cost, and accessibility is the prime reason for rise in the acquisition of the mobile sensors. Furthermore, their use as a health monitoring system helps collect relevant biophysical data which is used to make ameliorate diagnostics and medical resolution.

AI, Big data and IoT are interrelated research domain which affect and help improve modelling and advancement of amplified personal healthcare systems. Wearable medical systems integrated with Big data can be used to supply steady monitoring characteristics that will aide in the collection of high amounts of medical data, based upon which doctor, nurse can more accurately forecast patient's future condition. The knowledge extraction and data analysis involved is a complex operation that requires upgraded security method [1]

AI and Big data extend multiple opportunities for IoT based healthcare systems. Big data developing innovatives centered on AI can drastically build on worldwide community health. AIEIOMT technology reduces overall cost for chronic illnesses prevention a reality. The instantaneous health inputs gathered by such systems make assistance to the patents during self managing therapies. Mobile device applications are frequently applied and combined with mHealth and teletherapy via AIEIOMT.

The outcomes of telemedicine data analytics from these states enhance the materiality of data interpretations and reduce the time taken in data output analysis.[2]

Moreover, a novel system "Personalized Preventative Health Coaches" is established that keeps experience and are utilized in describing comprehend safety and well-being data. Sensor networks facilitate in the observation of individuals who do not have approach to an systematic healthcare monitoring system. Moreover integrating wireless communication with machine learning (ML) makes it possible to evaluate medicinal figures that assists doctor to construct apt exhortations. The manuscript presents an inclusive learning and broad applications of AIEIOMT in the medical fields. It examines which type of AIEIOMT systems were used in various areas of therapy and the methods that were utilized in compilation of clinical details in order to assist, inspect and analyse. The other objective of this paper is to construct a recent advancement of AIEIOMT technologies in healthcare.[3]

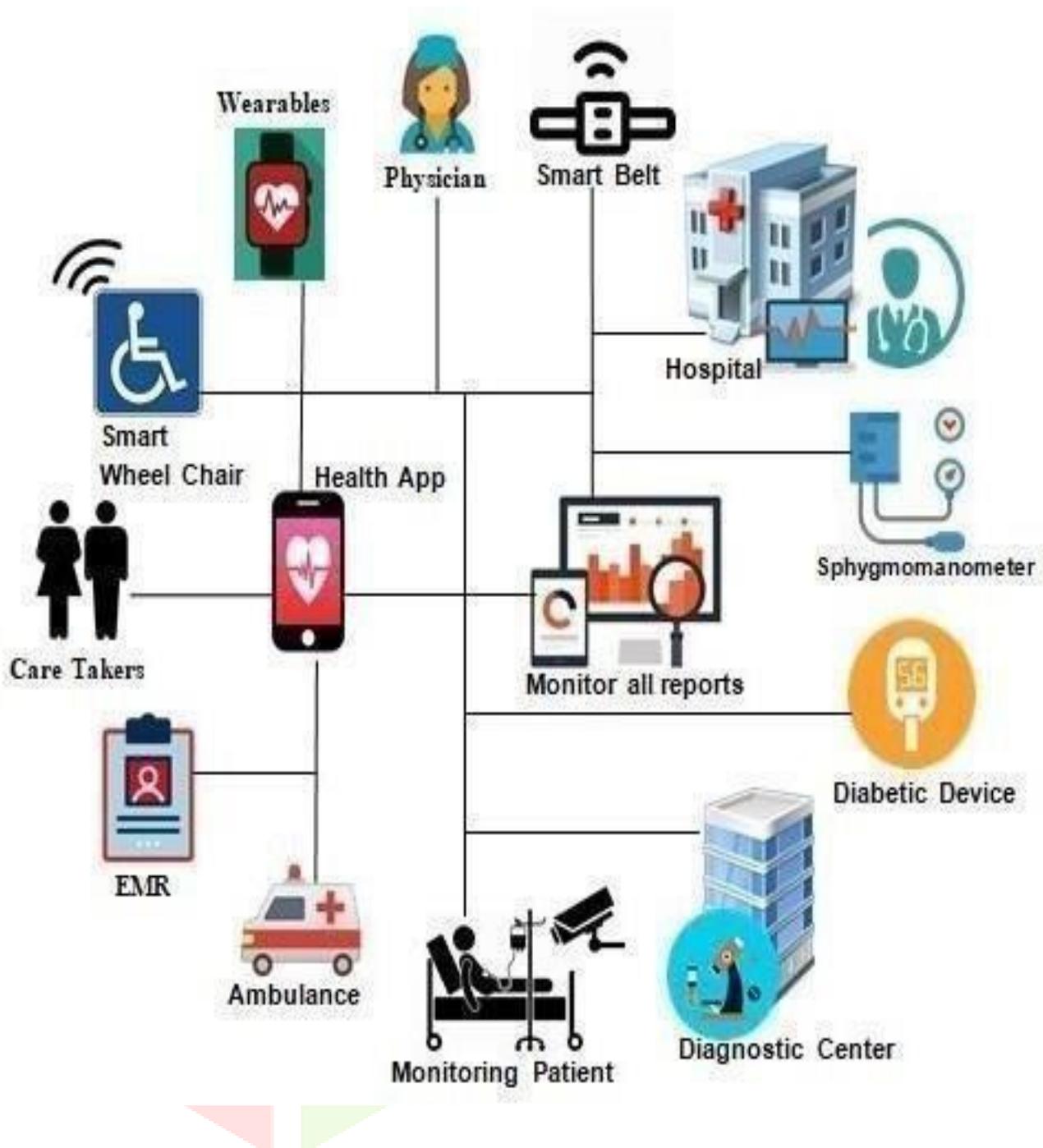


Fig.1- AI Enabled Internet of Medical Things

### **Advantages and effect of AIEIOMT**

AIEIOMT has many benefits to individuals, consumers, construction, society, Power distribution, manufacturing, business and industry. IoT based applications and systems have transformed the world which people of 90's thought about. IoT with AI has made revolutionary changes in the field of internet communication. It has lot of contributions in the development of many challenging domains but specially in the field of medical things. Due to these reasons it has closed the gap between the patient, doctors, and healthcare services by its ease, flexibility, accuracy and data sensing in real time. AIEIOMT enables the physicians and healthcare staffs to perform duty with better explicit and passionately with little effort and brainpower.

Figures 1 and 2 explains the outlook of patient and doctor components and high prospective influence of AIEIOMT.

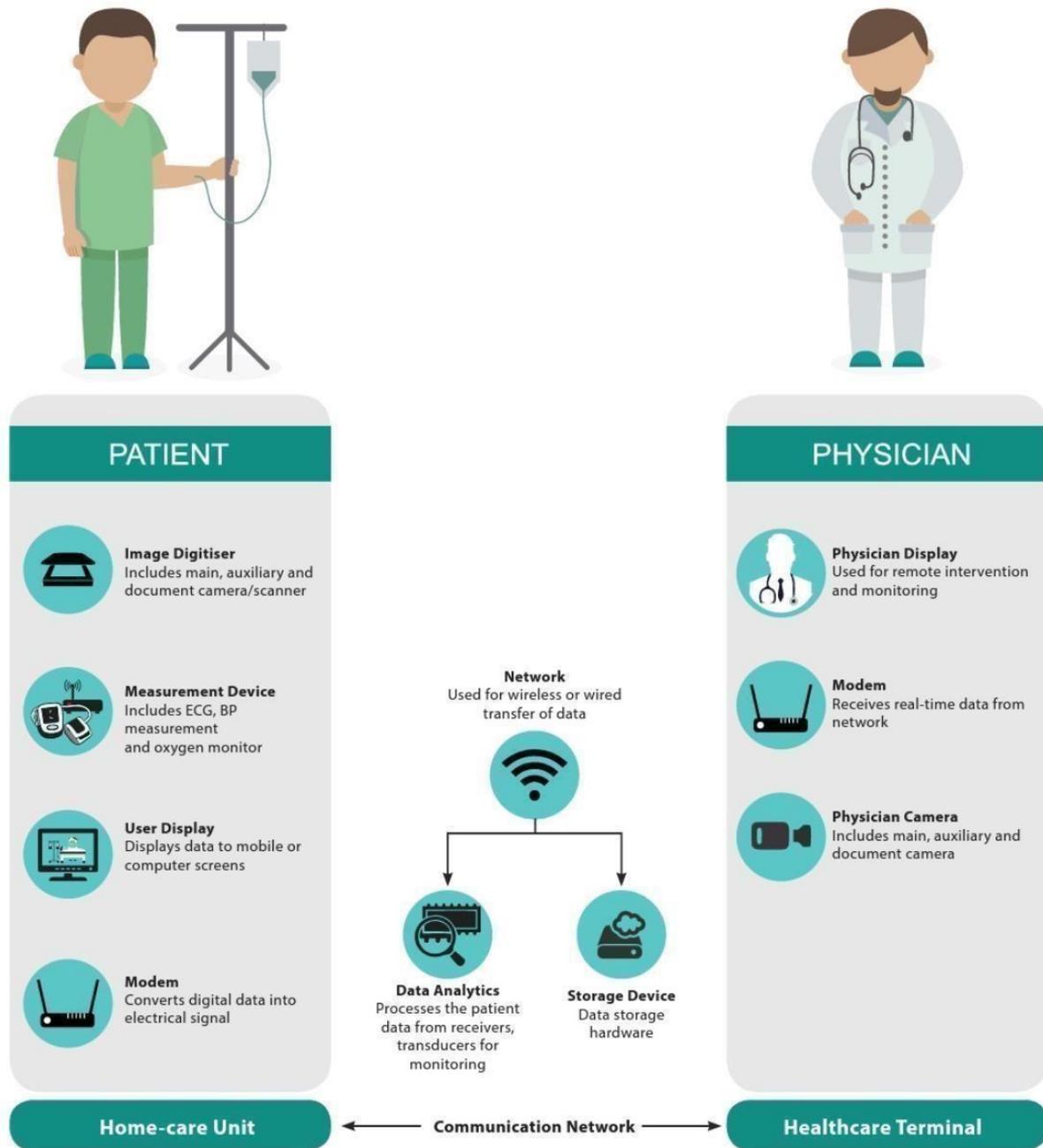


Fig.2- AIEIOMT Components

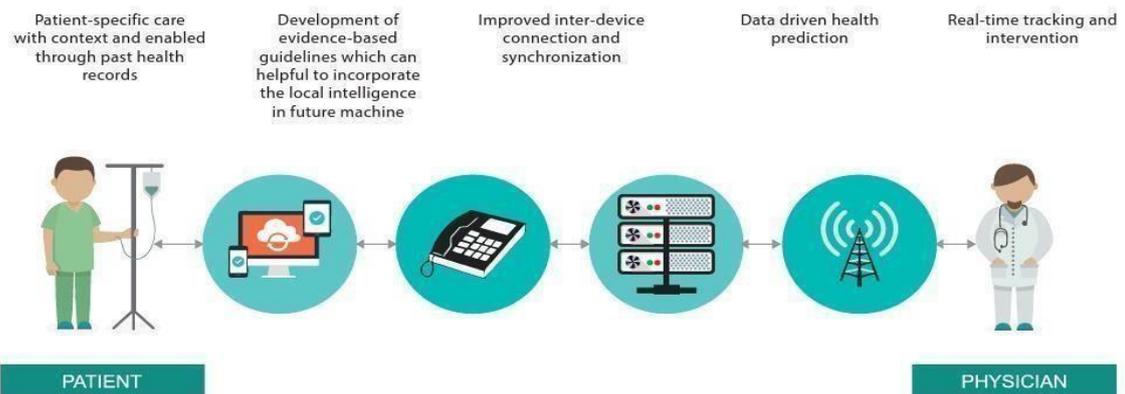


Fig.3 - AIEIOMT IMPACT

AIEIOMT strengthens the human-machine interactions and authorizes the real time health observing solutions and patient affiance in decision making. Benefits, applications and limitations of AIEIOMT execution are listed below. AIEIOMT develops real time healthcare monitoring system, maintenance, track record registration, to aid data driven decision. These acts like a regime for patient's personalized healthcare. Also key result areas of AIEIOMT implementation in healthcare are listed here.

### **Advantages of AIEIOMT**

#### **☆ Patient Benefits**

1. Real time intervention in exigency situation
2. Low cost
3. Prevalance reduction and economic load because of slighter follow up visits
4. Outcome of patient , life quality is improved
5. Real time and energy efficient disease prevention and management,

#### **☆ Health Care Service Providers**

1. Best consumption of infrastructure and assets
2. Latency in case of medical crisis
3. Simple and Easy to use, affordable, on time medication
4. Doctors can provide off time medical services also by IoT and AI
5. Doctors can manage patients record easily

#### **☆ Device Manufactures**

1. Standardiization / affinity and consistency of available data data
2. Potential to feel and carry heath related informations to isolated places
3. Automatic alert of major changes to different parties, save time and life
4. Heathier and longer lives
5. High user end experience

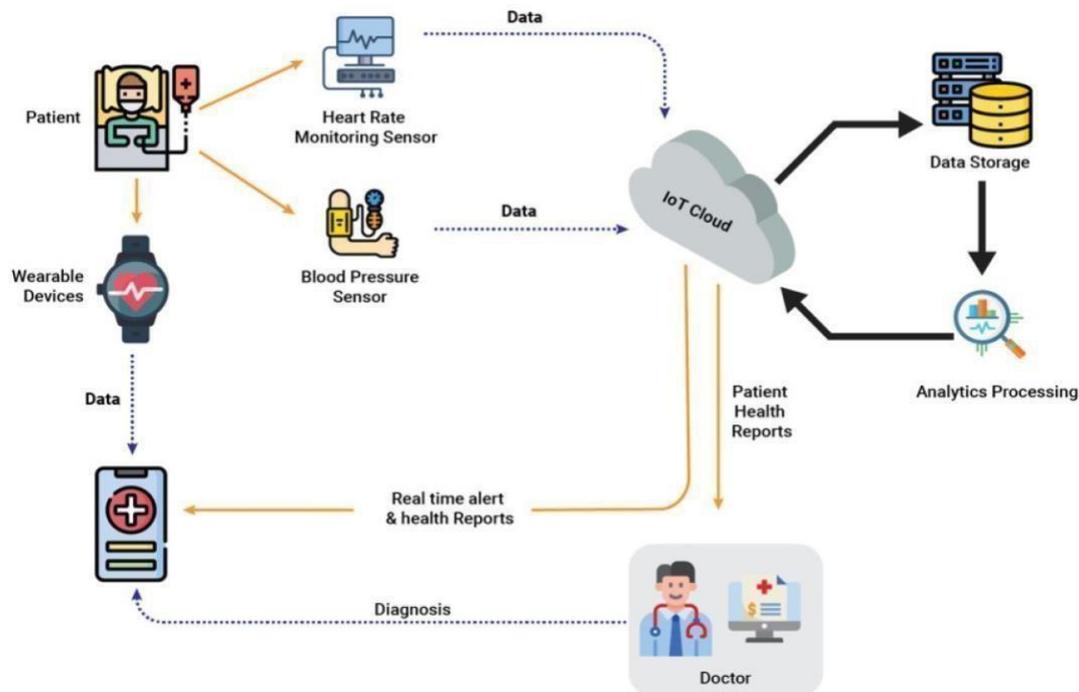


Fig.4 - IoT Transforming Healthcare Industry

### Application of AIEIOMT in Medical domain

1. Smart Rehabilitation system
2. Supervised learning based patient posture identification
3. Home healthcare monitoring system and decision making for neurologically disabled Patients
4. Smart nursing system
5. Safe and secured healthcare system
6. Smart hospital based on AI and IoT
7. Android electronic medical healthcare gadget
8. Ubiquitous medical healthcare monitor system
9. AIEIOMT based Kindney abnormality detection system using ultrasound scanning
10. Physiological patient condition monitoring
12. Cloud based Remote ECG
13. Autistic patient monitoring healthcare system
14. Obstructive sleep apnea (OSA) diseased patient monitoring
15. Medical Bot
16. Inexpensive arrhythmia management (ICarMa) system

**Limitations of AIEIOMT****☆ Technical Challenges**

1. Safety of AIEIOMT data-hacking and unaccredited use of AIEIOMT
2. Shortage of customary and transmission pacts
3. Inaccuracy in patient data management
4. Data amalgamation
5. Requirement for medicative skills
6. Handling system variegation and collaboration
7. Span, performance and data volume
8. Dvice managing diversity
9. Hardware implementation and design optimization issue
10. Memory of the system

**☆ Market Challenges**

1. Doctor consent
2. Data overburden on heathcare means
3. Mobile pausing
4. Security stratagem complaince
5. Modelling relationship between acquired measurement and diseases
6. Irregular, raising and varied data at exponential rate
7. Interoperability
8. Software execution of medical analytic strategy
9. Intellect in medical caution
10. Security challenges

**Integration of AI with IoT**

The Objective of AIEIOMT is to strengthen the healthcare systems and data acquisition taken from curative tools and its implementation. It utilizes a distinct types of sensors ,accelerometer sensor, temperature sensor, pressure sensor, CO<sub>2</sub> sensor, humidity sensor , visual sensors, Gyroscope sensor, cellular breathing sensor, saturated plasma oxygen sensor, electromyogram/electroencephalogram/ electrocardiogram sensors ( ECG) in real time heath monitoring of patients.

Such remedial appliances keep track of fitness states of patient's in order to collect clinical data and in sending these data to the doctors from remote data cloud storage centers.

The main challenge of AIEIOMT is in control and regulation of remedial application which creates huge amount of data from joined devices. The AIEIOMT tools and strategy are widely availed in the heart disease detection, heart disease diagnosis, disease detection and forecasting, and robotic surgery in healthcare. It includes basically a networked architecture which grants link between a patient and and medical competencies for illustration, IoT installed e-Health approach for electroencephaligram,

electrocardiogram, diabetes, heart rate and various other kinds of vital trait body monitoring biomedical sensors which include oxygen in blood ( SPO<sub>2</sub>), pulse, breathing (airflow), glucometer, galvanic skin retort, accelerometer ( patient situation), blood pressure, body temperature and electromyography.[4]

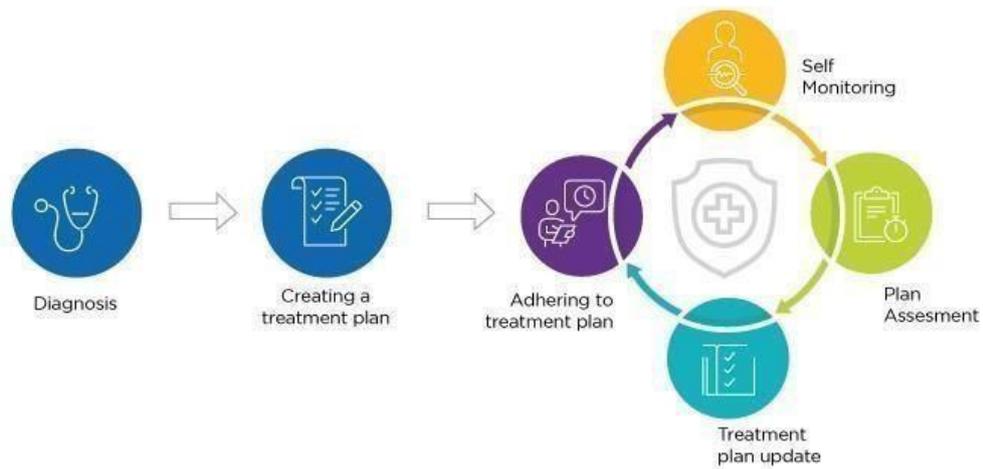


Fig. 5 - Standard protocol from clinical data creation to clinical resolution  
(Source-National Institute of Health(<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5829945/>))

### **Diagnosis of Heart Diseases**

Many research survey tells that machine learning algorithms (MLA), Support vector machine (SVM) and Naïve Bayes (NB) has the top foremost state in healthcare system mainly in disease related to heart and detection systems. A set of hyperplanes in infinite dimensional area can be developed by SVM to evaluate the rectilinear disconnecting aspect accompanied by utmost edge in a given datasheet of training. It can be also used in nonlinear regression and pattern analysis puzzles. Text classification, spam filtering, document categorization, news classification can be done by NB AI algorithm. This ML methods works well when all the input data are classified into predefined groups requiring less than logistic regression.

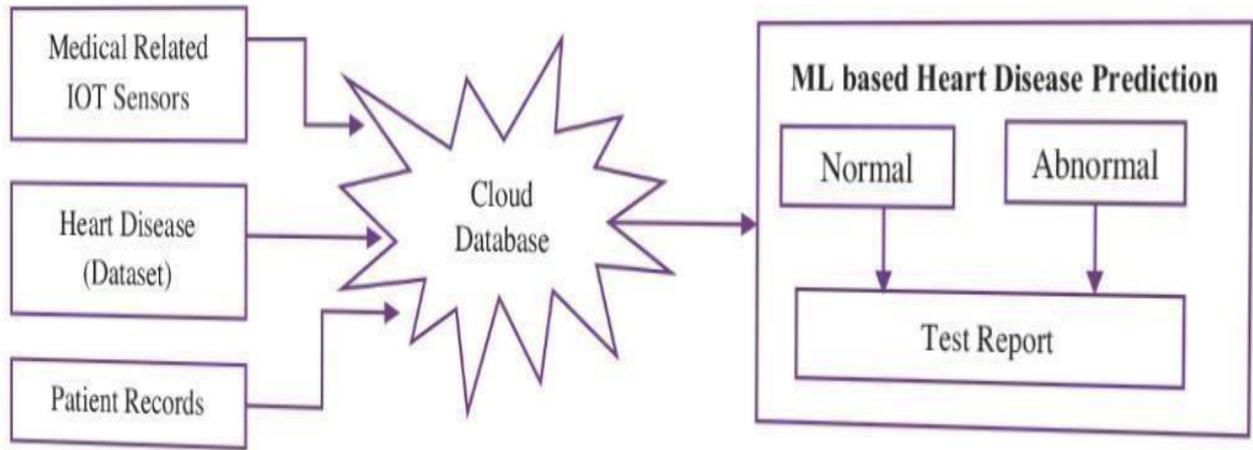


Fig. 6 – Diagnosis of Heart Diseases By AIEIOMT

Moreover, in atrial fibrillation detection mobile telemetry devices are essentially used. Real time monitoring of arrhythmia detection and heart rhythm are performed with these devices so that AI, machine learning systems and medical wearables can be used to develop for heart disease detection and identifying signs of heart disease investigation scanning data of earlier patients dependent on remote patient monitoring and analysis of previous data. However MLS is capable to forecast the probability of recurrence of cardiac-arrest in upcoming days. [5] Researchers at Mayo clinic examined that MLS, convolutional neural network (CNN) enabled ECG are made use in the examination of the heart's electric-powered exercise and inspect asymptomatic left ventricular dysfunction (ALVD). This research evident that CNN works on classify when patients with ventricular dysfunction having ejection fraction  $\leq 35\%$  this proves that AI based ECG appliances are cheap and ease to detect ALVD. [6]

Also, AI techniques consisting of deep learning (DL), Cognitive computing (CC), and Machine Learning (ML) are of great importance in development of cardiovascular medicine. Ejection fraction AI is useful in the classification of phenotypes and genotypes in several diagnostics echocardiographic parameters and new echocardiographic therapy high potential management. Disease diagnosis and medical analysis features can be filtered from sensors enabled AIEIOMT data with ReliefF algorithm. Onwards, optimized variables of LSTM neural network is obtained for foretell of powered network. Practically, it is possible to use promote MapReduce framework based efficient private data clustering scheme (EDPDCS) and cluster analysis which uses k-means algorithm by examining normalized intra-cluster variance (NICV) & grasshopper optimization with hybrid neural network system. The grasshopper NN algorithm has a great impact on problems related to optimization, ML mechanism to provide adaptive and flexible results in diabetes, orthopaedic, breast cancer, coronary heart disease and Parkinson's disease. [7]

Health Insurance Portability and Accountability Act consensus for personalized validation mechanism in respect of AI enabled Internet of medical things and depending upon Multiparty Trust Negotiation (MTN) which ensures relationship between IoT devices and personalized access control regulations on this ground it has been used in access control policies to fabricate IoT suitable for healthcare features with safety. MTN provides improvement in design, scalability, inflection, and patient health information.

For the sake of MTN secured safe data communication between doctors and medical things, Virtual Federation support and circle of Trust Soter framework is created to control dynamic and personalized

medical informations. A physical good function relates informations from AIEIOMT devices into a acceptable cloud-based memory and turn down the reduces the validation period from 1.2 to 1.5 seconds. Additionally, there are various cyber-security chassis (ISO 27,000 x series, COBIT, NISF CSF 2018) to regulate guidelines for AIEIOMT and its security but it has no any particular standard till now. AIEIOMT health tracking methodologies includes wide range of wearable devices capable of generating, fast, reliable, convenient real-time data about patient heart conditions and 3 tier viral architecture to build acquisition system regularly in actual time. [8]

### Predicting Methods

To improve the effectiveness of multi-dimensional prediction in respiratory outpatients NN models in conjugation with AIEIOMT and deep learning is implemented. Currently AIEIOMT authorize medical data collected with wearable device and sensor (Magnetic resonance, ultrasonic imagination and tomography). Practically CNN permits the development of recurrent neural network (RNN), stack auto-encoders (SAE), Deep belief networks (DBN) into the prognosis of patients coming condition by investigations of collected data by wearable devices and sensors. Various phases of machine learning stereotype of machine learning models uses intra-operative method to regulate result hypotheses of biomarker dialysis and machine learning data processing in real time are used by learners. [9]

Chronic kidney disease (CKD) is very dangerous disease therefore its prediction in early stage is necessary for the patients. These days, contingent on patients past data interpretation and subjected to cloud nature improvement and cloud-based environment improvement, healthcare services uses IoT to predict CKD stages with cloud based IoT Hybrid Intelligent Model (HIM) consisting Neural Network (NN) and linear regression (LR). NN is able to identify CKD stage and LR can determine CKD-seed factors. This method is very accurate (accuracy 97.8%, proved by HIM experiments). Also fuzzy neural classifier is used in prediction of diabetes diseases.

It includes depository spreadsheet with available curative data to detect upcoming conditions of patients. [10]

Disease Prediction Support System (DPSS) are helpful in data privacy and security techniques development in healthcare areas. Fuzzy neural network enabled Big data IoT sensors are used to estimate and calculate diabetes diseases next stage conditions and realizable problems felt by the patients.

The paillier homomorphic with Privacy-Aware Disease Prediction Support System (PDPSS) is the updated class of DPSS capable of saving source data from client. A IoT cloud subjected framework when combines with smart wearable devices is used to detect quantity of glucose in diabetes patients. Thus collected data is transferred to a cloud platform after that it is prepared by suitable methodology ML methods, decision tree (DT) and NN showed 94.5 accuracy in experimental investigations of "Pima Indians Diabetes" data AI algorithm uses NB, random tree, zero R programming, and J48 methods to identify level of glucose in diabetic patients. Additionally, machine learning algorithms like DT, SVM, K-NN, MLP and random forest are also useful in prediction of diabetes evolution. This history of use if cognitive AI for diabetes care systems starts from year 2009. However the patient self-management tools, clinical decision support, prognostic population risk stratification, automated retinal screening has are the imerging domains of research in AIEIOMT to assist the patients quality of life. [11]

In the identification of breast cancer Image augmentation, feature selection, features extraction, K-means cluster, pectoral muscle removal and artifact are included in GLCM third order features computer-assisted diagnosis (CADx) so that biomedical data can be collected by IoT.

Deep ML based Computer assisted decision support system is used to detect pulmonary cancer. Deep convolutional neural network (DCNN), deep fully convolutional network (DFCNet) methods are used in the diagnosis of pulmonary cancer in lungs and for early stage prediction of it. The accuracy of CNN and DFCNet are 77.6% and 84.58% respectively. [12]

Medical image security can be promoted by an innovative cryptographic model that are essential in storing patients data into cloud server with superior security methods.

Grasshopper optimization and Hybrid swarm optimization are of great importance for security of biomedical data /images is to be transmitted to a server and are used in encryption and decryption process data thus it provides exceptional security features in Big data AIEIOMT among all the cryptographic methods. [13]

### **Robotic Surgery**

20th century is also known era of robotic surgery. Due to better stability, tremor filtration, 3D views, faster rehabilitation recovery rate, minimum blood loss, less Adhesion robotic surgery are used nowadays in healthcare systems.

The current experiments exhibited endowristed instruments participation in the treatment of abdominal wall surgeon found perfect result for both patients and doctors. Transoral Robotic Surgery (TORS) with innovative retractors is efficacious gadget in visualization and characterisation of tissue, specially in larynx. Medrobotics system TORS having least risk of reconstruction during open surgery are used in surgery of disease such as papillomas, polyps, leukoplakias, and dysplasia and other related complications. [14]

Hard surgery methods such as atrial fibrillation ablation, coronary revascularization, mitral valve surgery the result of introducing robots in medical science. The hospitals and medical centres are increasing the use of surgery robots day by day due to its relevant outcomes in research studies and experiments, clinical efficacy, low cost and patient safety.

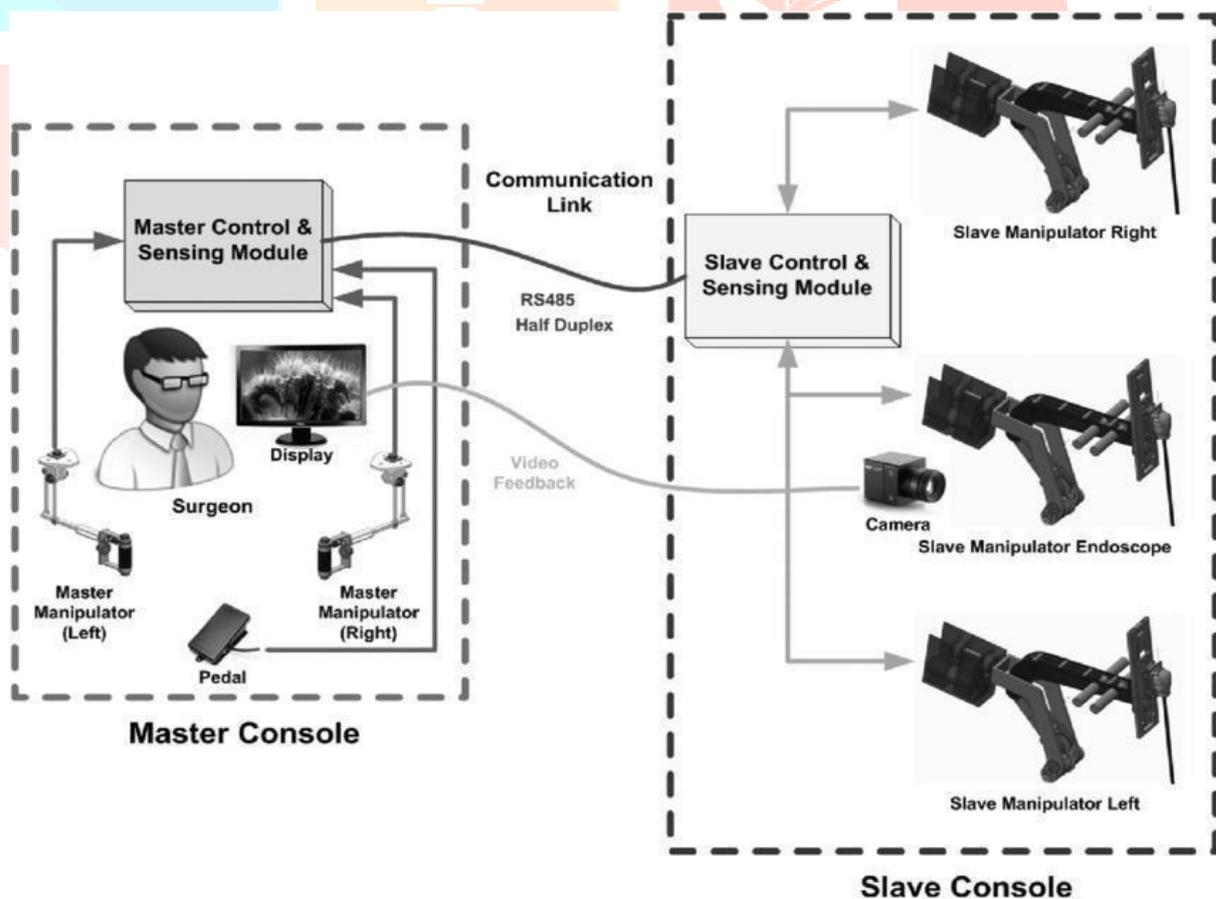


Fig. 7 - systematic block diagram of AI enabled Robotic Surgery

There are few disadvantages of robotic surgery such as risk of human error when operating a robotic system, potential of Mechanical Failure. For instance system components like as camera, robotic arms, binocular

lenses, robotic tower, and instruments can fail. Due to which it needs improvement in cardiopulmonary bypass and myocardial protection.

The endoscopic holder methods are supported by numerous ML and AI surgery robots specially in oropharyngeal cancer surgeon, transanal endoscopic skull base surgery having excellent accuracy than hybrid robots which is partly AI automated. [15]

Moreover, Minimally Invasive Surgical (MIS) with high accuracy and safety, requires the robotic assistance in high-risk surgery intervention. MIS works constantly throughout the operation, which inspire the further modifications in precision tools in smart robots which is essentially relevant in improving the capacities of the surgeons in visualization, collection of data and medical imaging. Robotics and IoMT have chances of promoting safety, accuracy and agile in healthcare centers entering into network anatomical domains and taking medical images on micron scale.

MIS is the forthcoming medical facility having IoT configured cybersecurity for medical Big data including envelope of energy reservoir dependent regulators and wave variable compensated teleoperation structure. Smart Tissue Autonomous Robot

(STAR) was useful in intestine surgeries in the year 2016. [16]

The experiments displays that STAR produces extra agile, clinical safe intervention and accuracy than human surgeons. It has need of human assistance in further steps of examination. It entitle surgery robots for new creation of self-governing and soft-tissue surgical robots having real time support of communication. As self-governing and soft-tissue surgical robots are remotely controlled systems trained by ML and AI algorithm. [17]

Even Big data of intra-operative diagnostics with 2D dimensions can be processed by HLC. For patient's data collection we use multiple sensors and ML & AI enabled statistical analysis. The miniature robots having tree hands (AESOP is one of them) and are able to enhance computerimproved colonoscopy techniques made up of Automated Endoscopic System, voice activated robotic endoscope for Optimal (AESOP) systems and system of master-slave. AESOP is voice controlled and featured with surgery visualization. If we use Zeus system, then functioning becomes more flexible and safe. It is remote monitored system and its cameras is capable of creating full images of surgeon room. Due to this reason, surgeons can remotely perform operation and directives from other locations also and can shift robotic arms (up/down/left/right) with reference of millimeters accuracy. [18]

### Personalized Treatment

In contemporary medical science, personalized treatment is becoming well-liked day by day. This implies collection and application of Big Data, data science, Machine learning integrated with medical devices to creat statistical system and gives accurate results in clinical practice. Use of ML and Big data in personalized treatment/medicine makes it more complex prognosis, authentic prediction model and trials of validate clinics.

Newly researches have shown the sustainable and reliable potentials of personalized medicine in the medicine world. There are five distinct sections of therapeutic medicine:- (1) AIEIOMT with Personalized Medicine (2) Individualized medicine accompanied by brilliant technology. (3) Graded medicine treatment procedure (4) Segmented medicine with Big data (5) Targeted therapies with cancer type classificatio. It is need of our present and future to improve, analyse, accurate, integrate & combine recent elevated technology, generation and exposition strategy of Big Data.

[19]

AI offers limitless Prospective and advancement of personalized treatment in medical sector, mainly in stastistical analysis and data science. In medical field, IoT, ML and AI altogether enables doctors to the collection, access, stock, and upgrade statistical analyses of patient's situation.

Deep neural network (DNN) has developed a DeepSurv system which combines state of the art survival method and Cox proportional hazards analyses. DeepSurv services personalized treatment recommends and makes statistical archetype patient's treatment efficacy.

Adoption of new technologies in medical domain has caused various fresh provocations in patient's treatment, specially in those patient's who needs more precise diagnosis and treatment. Thus, intelligent health monitoring systems are developed for better performance in real-time time health monitoring system ( example:- BioSenHealth 1.0) which produces things peak.com and utilizes cloud platform in transportation of live data between patient and doctors. BioSenHealth 1.0 is a prototype which can control heart rate/pulse rate, body oxygen level, and body temperature to assemble arithmetical examination of real-time data and displays visible plots.

In fact, Alzheimer's disease causes severe illness due to this reason, it needs daily tests. AIEIOMT has made this difficult process very easy and satisfactory of monitoring Alzheimer's disease patients through algorithms. [20]

In Hybrid feature vector combining methodology, use of this algorithm is able to make three dimensional view & statistical analysis of AIEIOMT during absolute picture of patient's situation. Experimental analysis of this algorithm tells that average percentage for binary and multi-class classifications are 99.2 % and 99.02 % respectively. Diabetes 1.0 and 2.0 are analysed with 5G-smart personalized treatment system which is combination of ML algorithms, Big Data methodology, & wearable 2.0 technology. This system works for those patients who are suffering from diabetes to investigate the progress of diabetes in human body. [21]

### **Diabetes treatment**

Due to increasing demand of AIEIOMT solutions are used in the treatment of diabetes where various wearable and portable monitoring devices ( insulin pens, insulin pumps, continuous glucose monitors, blood glucose monitors, and closed-loop Artificial pancreas systems are effective in wireless communication with tablet or smartphones, acting as margin nodes and provides cloudless rudimentary logical preservation.

Many new opportunities in this domain focuses different modes in order to predict the disease onset such as Abdel-Basset et al. [22] deliberate about unique methods to foresee type-2 diabetes risks, while [23] employes a decision tree classifier like J48Graft, executed on a smartphone to come across the endangered degree of diabetic patients. Also a Fog architecture proposed deep learning model is discussed in Priyadarshini et al. [24] to forecast diabetes, hypertension and stress types attacks from wearable sensor data.

### **Categorization of AIEIOMT**

AIEIOMT is capable of caring chronic diseases management, elderly patients and pediatric medical situations, and conditions of fitness and personalized health among the rest. For well understanding of this huge content AIEIOMT has been classified into four general categories:- 1) Remote healthcare monitoring; 2) Smartphone based healthcare solutions; 3) Ambient assisted living; and 4) Wearable devices. Next paragraph intricate each one by one.

#### **1. Remote Healthcare Monitoring**

Monitoring of remote healthcare technologies are basically embraced by hospitals, clinicians & homecare climate in remote detection of the vital indications of individual communication in realtime to parents, patients and physician a feasible deformity, bringing down the clinician time, reducing costs of hospitals facilities and upgrading class of care. Remote healthcare monitoring could be done by applying and acquiring physiological data from patient to be integrated remotely.

IoT when integrated with cloud storage, data communication infrastructure and mobile computing is applied to perform Internet connectivity, user interface (computer, tablet, desktop, android phones) collector (biosensors). This methodology points to store, turn, transmit, seize accessible biomedical visualization signals in real time. In the similar situation, middleware supported IoT platform is used to connect gadgets, healthcare providers and patients.

This is a kind of web platform which permit management of data and focus on the objectives of simplifying and IoT based application growth, directing matters such as interactivity between various devices. Serafim [25] introduced IoT network to regulate patient's condition in agricultural and areas having low population density. The role of healthcare in this context is to data exploration received from patients and ask for accidental support if needed. Mobile gateway based uhealthCare ubiquitous system works in similar fashion in collection, processing and storing of data stored in the remotely accessed cloud. A wireless network, intelligent personal digital assistant and medical server tiers formulated infrastructure is used to monitor remote healthcare system showed in figure 8.

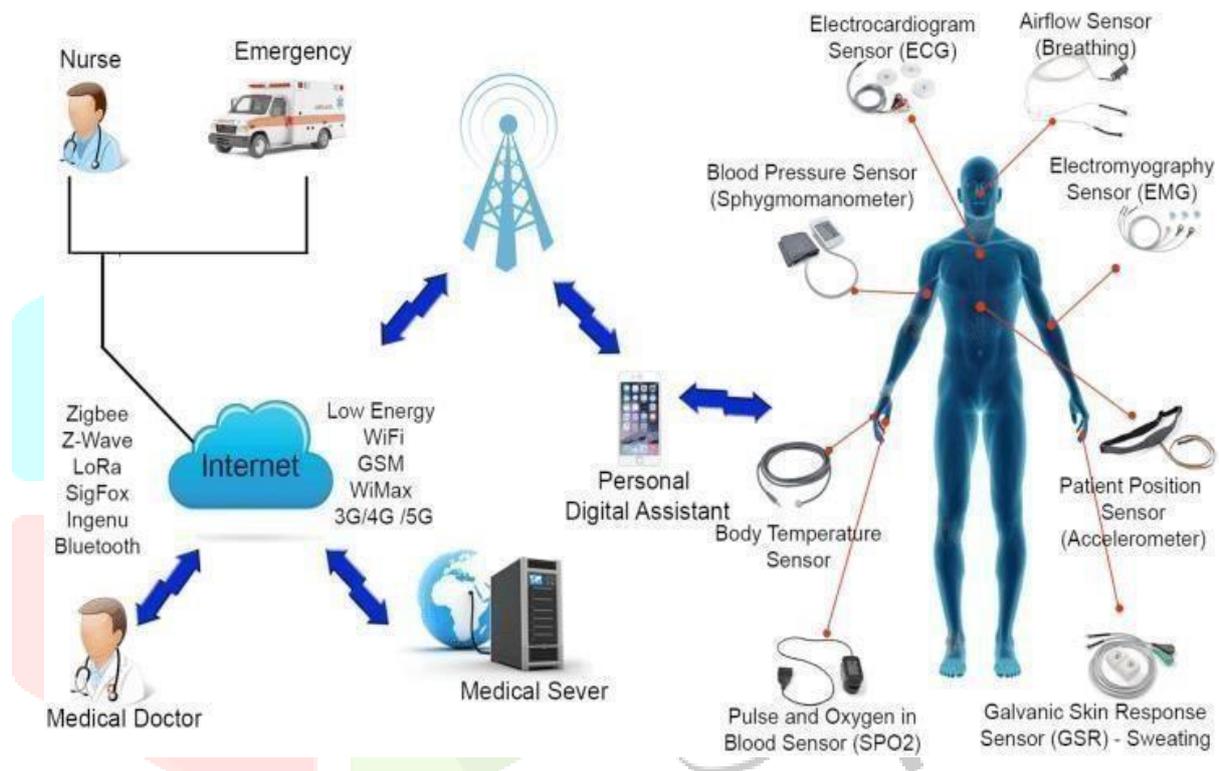


Fig.8- Demonstrations of remote healthcare monitoring system

Prototypes are the low cost technology superior system shows pre-processed data in United and unique way displays improved individual's quality of life. An embedded system is an inexpensive technology able to estimate blood has been expressed in [26].

Gadget hosted webpage shows data stored in more specific functional way healthcare professionals use this data directly by using Internet.

Mater et al. [27] proposed a remote body pressure monitoring system. This is useful in anesthetic surgery, sleep problems and other fields to determine body posture.

Un-invasive glucose sensor is introduced by Istepanian et al. [28] to send data from patients to healthcare providers in real time.

Humidity sensor and heart rate sensor prototype controls the Sjögren syndrome patients. mHealth system is able to monitor data collection transfer between patient and healthcare providers in seek cardiac rehabilitation. Body sensors are capable of processing, storing, accessing and monitoring of data by healthcare providers. These sensors can interconnect with user's smartphone to collect data.

A divination arrangement (Wanda-cardiovascular disease, CVD) to assist patient in lowering CVD hazard constituent detection and mankind are receiving informa by support of technology and reinforcement.

Remote health monitoring (RHM) prediction tools can add flavour in recognizing patient's behaviour during its intervention in early stage that aid regulate outcome success with satisfactory results (F-score =0.92). Efficiency and data privacy of RHM system can be improved by a secure privacy preserving data aggregation method which preserved data privacy authentically and confidently. RHM is faster than Apache sling method demonstrating an excellent execution, asynchronous, eventdriven healthcare hub server to hold a growing concurrent interrelation with RHM surrounding in remote areas without local medical excluding community medical abet to regional care. [29] Patient health monitoring (PHM) is an integrated IoT based cloud computational system utilized in treatment of congestive heart failure by ECG, conveying be a elastic, energy-efficient and accessible remote monitored patient healthcare system extremely encouraging.

Cloud based IoT system is used to detect and monitor Parkinson patients having low resources of healthcare. Distant self-monitoring of blood pressure to diagnose increased blood pressure in gestation period of women is calm to adopt and women favour the advanced system of test at their home.[30]

## 2. Smartphone based healthcare solutions

These days, ambient assisted living system or healthcare are unable to discover and design without including the mobile health assistance. Smartphones are used in various AIEIOMT solutions. Mobile Assistance in clinical communication, diagnosis, drug discovery and medical awareness are termed as healthcare solutions utilizing smartphones. It's objective is interconnect various types and smartphones, sensors and healthcare teams. Security is a major problem on AEIOMT, therefore project concerned testing if mobile devices should be used for data access.

The figure 9 illustrates the healthcare systems accompanied by mobile devices and smartphone apps.

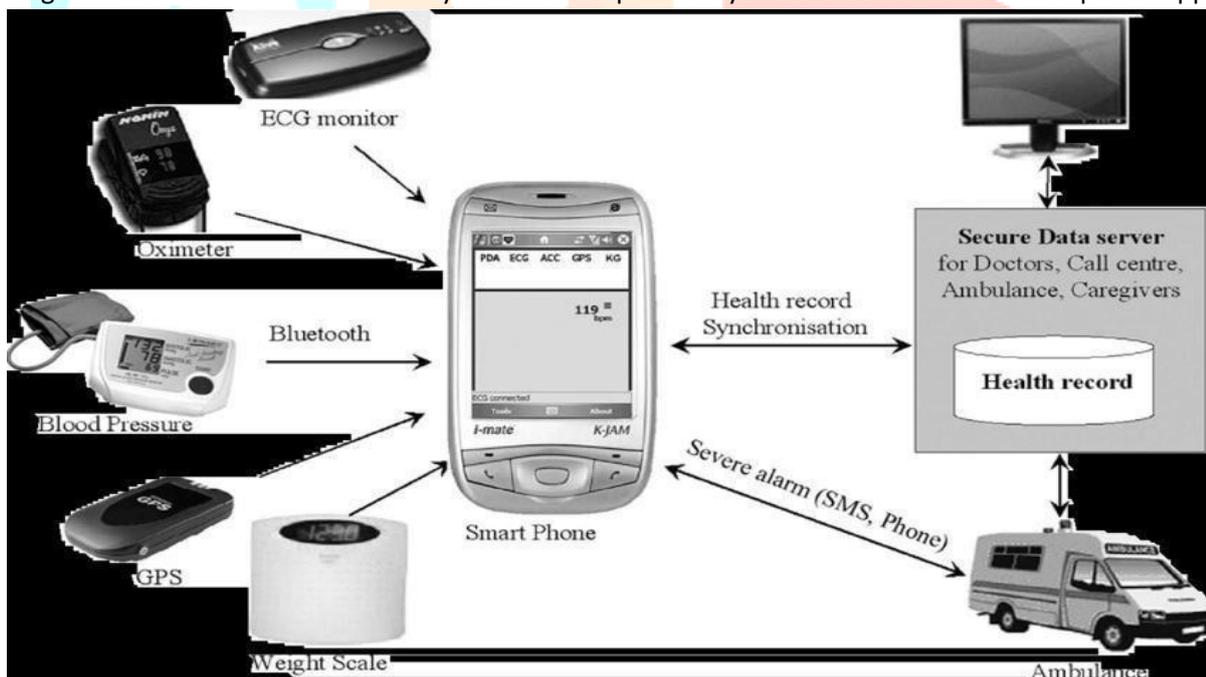


Fig.9- Architecture of Healthcare monitoring Using Smartphones

A medical check reminder is an effective solution which spontaneously dispatch information of scheduled appointment with a doctor one day prior to the patient's phone.

Shellington et al. [31] presented HealthBrain to provide indicators on acknowledging the square stepping exercise done by aged person at their homes without cognitive loss.

Virtual biosensor is a simple wearable instrument based on facile analog front ends and communication interfaces and processes raw biosignals with enlarging potential of mhealth application.

Virtual type sensors are used to analyze the heart and respiratory conditions.

A smartphone based system for real time tele-monitoring of vital symptoms and common cardiovascular signs conviction physical actions in heart disease patients, facing leading disputes to use in hypertension, chronic diseases and diabetes proposed by Aranki et al.[32]

Smartphones with IoT strengthens medicine having direct influence on people's daily life, which is significant contribution in medical field.

Smartphone accelerometer when linked to body, hand, bag, pocket, belt etc. signifies spatiotemporal variables in acquiring, processing and storing inertial sensors data, bipolar disorder, rotational matrix and orientation of gait variables evaluation in everyday life.

Cardiovascular abnormality can be recognized by remotely controlled wearable smartphones. mhealth systems are the machine learning algorithms embedded in mobile application used to analyze, and detect chronic wound images solely by android phones.

Smartphones are also implemented in skin monitoring and early detection of melanoma by prediagnosis at homes so that it can be treated successfully. Comprehensive information of sexual problems can also be applicable in desirableness and supplicates in amongst boys and girls of teenage.

Brayboy et al. [33] established a gratuitous smartphone, named Girl Talk, carrying encyclopedic promiscuous wellness information, and dictate the application's application's desirability and entreat among teenage girls.

### 3. Ambient assisted living

Ambient assisted living (AAL) is a type of IoT dependent resource which hold up safe keeping of aged or disabled patient. olution may enlarge the self-supporting existence of individuals in their houses imparting extra safety. Users can be connected by the smart objects like motion sensors, blood pressure sensors these are common usage of this kind of facility. AAL not only gives the shielded environment but also grows self-governed users experiencing an additional mobile living. Figure 10 presents an ambient assisted living cycle whole realistic architectonics.

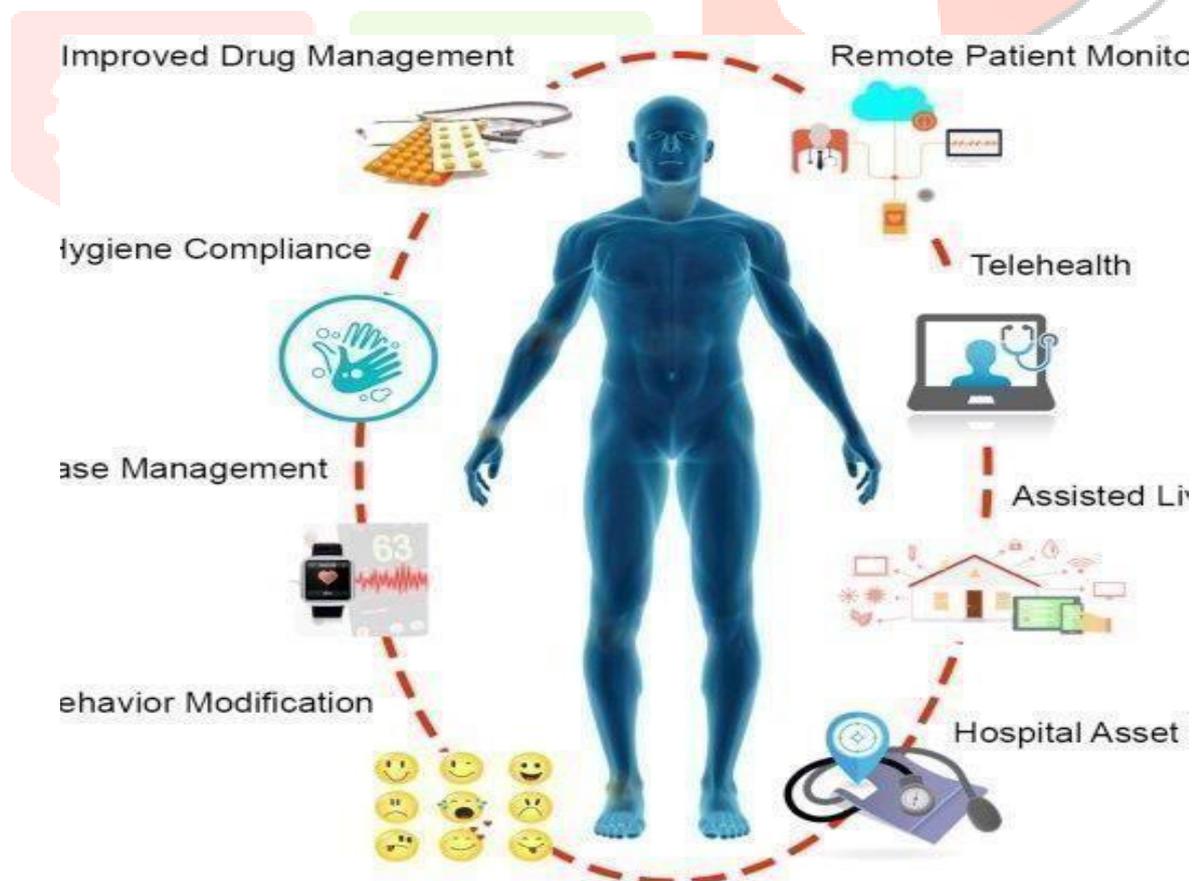


Fig.10- Architecture of an ambient assisted living system

Valera et al. [34] developed an IoT based architecture for AAL. An IoT based architecture is employed to provide its solution of complex problems like security and mobility in medical investigation and is given by Valera et al. [35]. Another kind of IoT based software architecture is Mhub, which makes use of cloud for AAL and by the use of middleware in mobile gadget it spontaneously realizes and joins with smart devices. In this aspect, another architectural framework is known as "H3IoT" is developed to monitor health conditions of elderly people. It consists of five layers of IoT including microcontrollers, sensors interconnectivity, communication channels and other important applications. A fall detection system is designed for elderly patient's mobility, locality, monitoring, and detection activities like running, walking, standing up, sitting, falling, riding, lying down. Each of the above mentioned activity is categorized by using AI integrated IoT architecture to detect set of instructions in real time location monitoring of aged people by computing network.

Drug compliance is the major issue of AAL, due to this concern new devices can help patient's security to keep up diabetes therapy management and regulates patient's personal data and joins this with health care professionals.

Bleda et al. [36] described that smart sensory furniture sensory layer (ambient assisted living system) which permits work out a probable menacing activity of aged person living at their home) spreaded processing technology in network sensing items highly scattered, coupled physically, network wirelessly and limited energy.

Liu et al. [37] explained a sleep scheduling mechanism (SSM) based on logical correlation to carry out energy empowered wireless sensor networks in ambient-assisted homes (AAH).

SSM examines the sensory data produced by various human conducts to discover scientific correlation of sensor nodes in AAH.

Rafferty et al. [38] established a new concept of implementation of assistive smart homes enabled recognition mechanism integrate agent architecture. There are three different scenarios of operation of this method :- (a) web interface focusing on testing the intention recognition mechanism; (b) involved retrofitting a home with sensors; (c) Supplying encouragement besides tangible undertakings.

Robots also assisted the surrounding life with various axims for joining robotization and selfregulation at residence.

Selection of particular sensor which can be utilized for introducing well founded classification replica, reducing cost of AAL system to facilitate algorithm execution on gadgets with restricted resources and very few sensors is an example of generic featured engineering approach. Multi-tier AAL is used to optimization of resources while providing constraint performance. RFID is a genius system which is used in identifying user-object interlinkage with the help of machine learning models in enabling the AAL system to retail outlet having precision rate of 86% [39].

AAL is helpful in managing health and goodness dynamically adapting gardening.

AAL integrated system design is capable of collecting, recording, and transmitting through IoT approach, where information may be rated and passed on over internet between smart objects and a different sensors placed in house of a person having dementia.

#### **4. Wearable Devices**

Wearable devices can monitor user's physical activity. Sensors when located on patient's body, shoes watches, clothes are used to monitor their health parameters. It makes connectivity between physiological transducers and patient's signal (heart rate, body hotness, blood pressure etc). They are needed when patient clicks on a button and directs necessary data like as blood pressure, heart rate, and oxygen saturation to the healthcare professionals for investigation.



Fig.11- Illustration of different types of Wearable technology

There are some more specific wearable devices which are needed out to streamline the operation infrastructure of health information system from its originating source and offer traces of data routes from them.

Due to complications in matching and mapping of device data to users, they need a developed Petri Nets, to track and detect medical data compromises. IoT + fog concepts in RHM system is useful in diagnosis and control of chikungunya virus. Fuzzy-C means algorithm diagnose the infected patients and capable of generating energy alerts. [40]

A conjunctive and cognitive similarity hierarchical combinative trial paradigms and clustered algorithm formed on definite state appliance to resolve issues of wearable arrangements because of innumerable states normally dominate to many unexpected problems. FSM manipulators are basically used in smartphone system design and its specifications for testing of black box. [41]

**AIEIOMT Industrial Importance**

The growth of AIEIOMT is undergoing an eminent discussion with investigation. Modern business, firm, companies, start-ups, and international companies, and multinationals agencies are enchanting a footstep to approach a huge export, import and advancing manufacturing an empowerment. Table 1 gives a brief description of AIEIOMT solutions available now in the market.

**Table 1. Some known AIEIOMT solutions from industry**

<b>Service</b>	<b>Company</b>	<b>Product</b>	<b>Brief illustration</b>
Ambient assisted living	Assisted Living Technologies Inc.	BeClose Remotely monitored system	BeClose Remote monitoring system provides sensation of consolation and sovereignty to both caretaker and deprived person.
	Fade	Fade :- Fall Detector ( App)	Fade is an application for the Android Gadgets able to detect and send alarm message when an individual suffers a fall.
Heathcare Solutions Using Smartphones	Mcare	Mcare ( App)	Mcare is a armllet that indicates parents whenever the children move away.
	Safe Heart	iOximeter ( App)	An oximeter for smartphones.
	Medisafe	Medisafe ( App)	Medisafe is a product that acts as a medication reminder.

		On Track	On Track Diabetes ( App)	OnTrack permits rapidly and comfortably keep tracking of everything required to control diabetes.
Remote Monitoring	Healthcare	EarlySense	EarlySense All-in-one	Incessantly monitors heart and respiratory rates, fall prevention, pre-diagnosis of patient deterioration and pressure ulcer prevention
		NovaSom	AccuSom	It is used to monitor people sleeping
		Hi Technologies	Tele-ECG	System of records of electrocardiogram
		Proteus Digital Health Inc.	Proteus Discover	Proteus Digital health consists of ingestible sensor, a small portable gadget and a provider . In this case, the pill dissolves in the stomach and produces a small signal that is picked up by a sensor used in the body, which again replays the data ( patients heath information) to a smartphone application.
Wearables		MC10	BioStampRC	Body sensor so elastic and mushy used in collecting data from patients to help research and development.
		Apple	Apple Watch	It allows the developer community to construct an infinite number of new applications for Heathcare.

	Bittium	Enterprise	Enterprise provides custom-made , secured IoT solutions and other technical services for healthcare, industry, and wearable sports gadget manufacturing.
	Qardio	QardioCare	A device able to track our all heart problems
			on our smartphone and can share stored data with physicians.
	Owlet	Smart Sock 2	Smart Sock 2 utilizes pulse oximetry to record our infant's heart rate and oxygen level in sleeping mode .
	Monica Heathcare	Monica AN24	Solution for remote monitoring and household clinical regulation.

## Conclusions

AIEIOMT and personalized healthcare systems perceive the local as well global support of collected data from medical devices. It is very vast sector which incorporate AIEIOMT blockchain in medicine, Big data, AI, ML , mHealth things, IoT in healthcare, digital health arrangement, fitness informatics safety, ambient sensors, privateness methodologies, robotics in Healthcare Industry and ultization and application of diverse modes in the divergent areas of medicine.

Education about AIEIOMT evidences that classification tree, LR, regression tree, NB, support vector recursive partitionig, K-nearest neighbors, SVM and randomly creation and merging of multiple decision tree into a single forest are the mostly operated AI techniques. All these techniques have been used to examine and compute the stored patient's data to upgrade health conditions belonging to them.

Concerning the heart disease detection, the prime use of AI algorithm are SVM, EDPDCS, RFRS, Deep Learning multilayered perceptrons, numerical taxonomy, NB, RFRS, cluster analysis. K-nearest neighbors and CNN are most commonly used predictive methods.

Moreover, systems related to robotic surgery ( da vinci Surgical appratus) are pertinent to aid heathcare professionals. Even so non-self governed automation ( AESOP, TORS) provides fewer hostile treatments leading various advantages which results in concerning haemorrhage and speedy recuperation.

AIEIOMT and its personalized healthcare implementation direct innumerable heath manifestation like as diabetes, biophysical parameters supervision and support system in decision making. In this paper , we have discussed the overview of Artificial Intelligence Enabled Internet of Medical Things and

technology, service applications related to it in medical field. Most relevant trending applications have been identified and many research opportunities are recognized, which can be emerging research area in near future.

## References

- [1] Internet of Things (IoT): number of connected devices worldwide from 2012 to 2020 (in billions). <https://www.statista.com/statistics/471264/iot-number-of-connected-devices-worldwide/>
- [2] Institute of health metrics and evaluation, 2015 <http://www.healthdata.org/pakistan>
- [3] Kaur, P., Kumar, R., Kumar, M.: A healthcare monitoring system using random forest and internet of things (IoT). *Multimed Tools Appl.* 78, 19905–19916 (2019). <https://doi.org/10.1007/s110420197327-8>
- [4] Manogaran, G., Chilamkurti, N., Hsu, C.-H.: Emerging trends, issues, and challenges in internet of medical things and wireless networks. *Pers. Ubiquit. Comput.* (2018). <https://doi.org/10.1007/s00779018-1178-637>. Kaur, P., Sharma, N., Singh
- [5] Cielen, D., Meysman, A., Ali, M.: *Introducing Data Science: Big Data, Machine Learning, and More, Using Python Tools*. Manning Publications, Shelter Island, NY (2016)
- [6] Attia, Z.I., Kapa, S., Lopez-Jimenez, F., McKie, P.M., Ladewig, D.J., Satam, G., Pellikka, P.A., Enriquez Sarano, M., Noseworthy, P.A., Munger, T.M., Asirvatham, S.J., Scott, C.G., Carter, R.E., Friedman, P.A.: Screening for cardiac contractile dysfunction using an artificial intelligence-enabled electrocardiogram. *Nat. Med.* 25, 70–74 (2019). <https://doi.org/10.1038/s415910180240-2>
- [7] Allouzi, M.A., Khan, J.I.: Soter: trust discovery framework for internet of medical things (IoMT). In: 2019 IEEE 20th International Symposium on “A World of Wireless, Mobile and Multimedia Networks” (WoWMoM), pp. 1–9. IEEE, Washington, DC, USA (2019). <https://doi.org/10.1109/WoWMoM.2019.8792971>
- [8] Yanambaka, V.P., Mohanty, S.P., Kougianos, E., Puthal, D.: PMsec: physical unclonable function based robust and lightweight authentication in the internet of medical things. *IEEE Trans. Consumer Electron.* 65, 388–397 (2019). <https://doi.org/10.1109/TCE.2019.2926192>
- [9] Manogaran, G., Varatharajan, R., Priyan, M.K.: Hybrid recommendation system for heart disease diagnosis based on multiple kernel learning with adaptive neuro-fuzzy inference system. *Multimed Tools Appl.* 77, 4379–4399 (2018). <https://doi.org/10.1007/s11042-017-5515-y>
- [10] Jin, Y., Yu, H., Zhang, Y., Pan, N., Guizani, M.: Predictive analysis in outpatients assisted by the internet of medical things. *Future Gener. Comput. Syst.* 98, 219–226 (2019). <https://doi.org/10.1016/j.future.2019.01.019>

- [11]Kumar, P.M., Lokesh, S., Varatharajan, R., Chandra Babu, G., Parthasarathy, P.: Cloud and IoT based disease prediction and diagnosis system for healthcare using Fuzzy neural classifier. *Future Gener. Comput. Syst.* 86, 527–534 (2018). <https://doi.org/10.1016/j.future.2018.04.036>
- [12]Kaur, P., Kumar, R., Kumar, M.: A healthcare monitoring system using random forest and internet of things (IoT). *Multimed Tools Appl.* 78, 19905–19916 (2019). <https://doi.org/10.1007/s110420197327-8>
- [13]Masood, A., Sheng, B., Li, P., Hou, X., Wei, X., Qin, J., Feng, D.: Computer-assisted decision support system in pulmonary cancer detection and stage classification on CT images. *J. Biomed. Inform.* 79, 117–128 (2018). <https://doi.org/10.1016/j.jbi.2018.01.005>
- [14]Zappa, F., Mattavelli, D., Madoglio, A., Rampinelli, V., Ferrari, M., Tampalini, F., Fontanella, M., Nicolai, P., Doglietto, F., Agosti, E., Battaglia, P., Biroli, A., Bresson, D., Castelnuovo, P., Fiorindi, A., Herman, P., Karligkiotis, A., Locatelli, D., Pozzi, F., Saraceno, G., Schreiber, A., Verillaud, B., Turri Zanoni, M.: Hybrid robotics for endoscopic skull base surgery: preclinical evaluation and surgeon first impression. *World Neurosurgery*. S1878875019327706 (2019). <https://doi.org/10.1016/j.wneu.2019.10.142>
- [15]Panesar, S., Cagle, Y., Chander, D., Morey, J., Fernandez-Miranda, J., Kliot, M.: Artificial intelligence and the future of surgical robotics. *Ann Surg.* 270, 223–226 (2019). <https://doi.org/10.1097/SLA.0000000000003262>
- [16]De Momi, E., Ferrigno, G.: Robotic and artificial intelligence for keyhole neurosurgery: The ROBOCAST project, a multi-modal autonomous path planner. *Proc. Inst. Mech. Eng. H.* 224, 715–727 (2010). <https://doi.org/10.1243/09544119JEIM585>
- [17]Elhoseny, M., Shankar, K., Lakshmanaprabu, S.K., Maselena, A., Arunkumar, N.: Hybrid optimization with cryptography encryption for medical image security in internet of things. *Neural Comput. Appl.* (2018). <https://doi.org/10.1007/s00521-018-3801-x>
- [18]Lanfranco, A.R., Castellanos, A.E., Desai, J.P., Meyers, W.C.: Robotic surgery: a current perspective. *Ann. Surg.* 239, 14–21 (2004). <https://doi.org/10.1097/01.sla.0000103020.19595.7d>
- [19]Schork, N.J.: Artificial Intelligence and Personalized Medicine. In: Von Hoff, D.D. Han, H.(eds.) *Precision Medicine in Cancer Therapy*, pp. 265–283. Springer International Publishing, Cham (2019). [https://doi.org/10.1007/978-3-030-16391-4\\_11](https://doi.org/10.1007/978-3-030-16391-4_11)
- [20]Katzman, J.L., Shaham, U., Cloninger, A., Bates, J., Jiang, T., Kluger, Y.: DeepSurv: personalized treatment recommender system using a Cox proportional hazards deep neural network. *BMC Med. Res. Methodol.* 18, 24 (2018). <https://doi.org/10.1186/s12874-018-0482-1>

- [21]Chen, M., Yang, J., Zhou, J., Hao, Y., Zhang, J., Youn, C.-H.: 5G-smart diabetes: toward personalized diabetes diagnosis with healthcare big data clouds. *IEEE Commun. Mag.* 56,16–23 (2018).  
<https://doi.org/10.1109/MCOM.2018.1700788>
- [22]Abdel-Basset M., Manogaran G., Gamal A., Chang V. A novel intelligent medical decision support model based on soft computing and IoT. *IEEE Internet Things J.* 2019:1–11.
- [23]Devarajan M., Subramaniaswamy V., Vijayakumar V., Ravi L. Fog-assisted personalized healthcare-support system for remote patients with diabetes. *J. Ambient Intell. Humaniz. Comput.* 2019;10:3747–3760.
- [24]Priyadarshini R., Barik R., Dubey H. Deepfog: fog computing-based deep neural architecture for prediction of stress types, diabetes and hypertension attacks. *Computation.* 2018;6(4):62.
- [25]E. Serafim, “Estrutura de rede baseada em tecnologia IoT para atendimento médico em áreas urbanas e rurais,” M.S. thesis, Programa de Mestrado em Ciência da Computação, Faculdade Campo Limpo Paulista, São Paulo, Brazil, 2014.
- [26]E. C. S. Dantas, “Low cost embedded hardware for blood pressure measurement based on Internet of Things,” M.S. thesis, Programa de Pós-Graduação em Engenharia Elétrica, Inst. Federal de Educação, Ciência e Tecnologia da Paraíba, João Pessoa, Brazil, 2016.
- [27]G. Matar, J.-M. Lina, J. Carrier, A. Riley, and G. Kaddoum, “Internet of Things in sleep monitoring: An application for posture recognition using supervised learning,” in *Proc. 18th Int. Conf. e-Health Netw., Appl. Services*, Sep. 2016, pp. 1–6
- [28]R. S. H. Istepanian, S. Hu, N. Y. Philip, and A. Sungoor, “The potential of Internet of m-health Things ‘m-IoT’ for non-invasive glucose level sensing,” in *Proc. Annu. Int. Conf. IEEE Eng. Med. Biol. Soc.*, Aug./Sep. 2011, pp. 5264–5266.
- [29]N. Alshurafa, C. Sideris, M. Pourhomayoun, H. Kalantarian, M. Sarrafzadeh, and J.-A. Eastwood, “Remote health monitoring outcome success prediction using baseline and first month intervention data,” *IEEE J. Biomed. Health Inform.*, vol. 21, no. 2, pp. 507–514, Mar. 2017.
- [30]R. Ganapathy, A. Grewal, and J. S. Castleman, “Remote monitoring of blood pressure to reduce the risk of preeclampsia related complications with an innovative use of mobile technology,” *Pregnancy Hypertension, Int. J. Women’s Cardiovascular Health*, vol. 6, no. 4, pp. 263–265, 2016. [31] E. M. Shellington, T. Felfeli, R. Shigematsu, D. P. Gill, and R.J. Petrella, “HealtheBrain: An innovative smartphone application to improve cognitive function in older adults,” *MHealth*, vol. 3, May 2017, Art. no. 17.
- [32]D. Aranki, G. Kurillo, P. Yan, D. M. Liebovitz, and R. Bajcsy, “Real-time tele-monitoring of patients with chronic heart-failure using a smartphone: Lessons learned,” *IEEE Trans. Affect. Comput.*, vol. 7, no. 3, pp. 206–219, Jul./Sep. 2016.

- [33]L. M. Brayboy et al., "Girl talk: A smartphone application to teach sexual health education to adolescent girls," *J. Pediatric Adolescent Gynecol.*, vol. 30, no. 1, pp. 23–28, 2017.
- [34]A. J. J. Valera, M. A. Zamora, and A. F. G. Skarmeta, "An architecture based on Internet of Things to support mobility and security in medical environments," in *Proc. 7th IEEE Consumer Commun. Netw. Conf.*, Jan. 2010, pp. 1–5.
- [35]B. Gomes, L. Muniz, F. J. da Silva, L. E. T. Ríos, and M. Endler, "A comprehensive cloud-based IoT software infrastructure for ambient assisted living," in *Proc. Int. Conf. Cloud Comput. Technol. Appl.*, Jun. 2015, pp. 1–8.
- [36]A. L. Bleda, F. J. Fernández-Luque, A. Rosa, J. Zapata, and R. Maestre, "Smart sensory furniture based on WSN for ambient assisted living," *IEEE Sensors J.*, vol. 17, no. 17, pp. 5626–5636, Sep. 2017.
- [37]W. Liu, Y. Shoji, and R. Shinkuma, "Logical correlation-based sleep scheduling for WSNs in ambient assisted homes," *IEEE Sensors J.*, vol. 17, no. 10, pp. 3207–3218, May 2017.
- [38]J. Rafferty, C. D. Nugent, J. Liu, and L. Chen, "From activity recognition to intention recognition for assisted living within smart homes," *IEEE Trans. Hum.-Mach. Syst.*, vol. 47, no. 3, pp. 368–379, Jun. 2017.
- [39]R. Parada, J. Meliá-Seguí, M. Morenza-Cinos, A. Carreras, and R. Pous, "Using RFID to Detect Interactions in Ambient Assisted Living Environments," *IEEE Intell. Syst.*, vol. 30, no. 4, pp. 16–22, Jul./Aug. 2015.
- [40]S. K. Sood and I. Mahajan, "Wearable IoT sensor based healthcare system for identifying and controlling chikungunya virus," *Comput. Ind.*, vol. 91, pp. 33–44, Oct. 2017.
- [41]K. Cui, K. Zhou, T. Qiu, M. Li, and L. Yan, "A hierarchical combinatorial testing method for smart phone software in wearable IoT systems," *Comput. Electr. Eng.*, vol. 61, pp. 250–265, Jul. 2017.