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# Chapter 10: Enabling personalized and preventive healthcare through intelligent embedded systems

## 10.1. Introduction

The significance of information and communication technologies has not only transformed the operations of many traditional industries, but has also made a solid impact on healthcare and medical sectors. Health is a critical factor affecting the production of labor and the process of social development in communities, not only on personal well-being. Moreover, information technology applied in health and medicine addresses the efficiency problem and quality management in the healthcare system which is urgent under the background of aging population, means of medical care and treatment becoming uproariously expensive, the medicine safety lush in the world and the contrast of medical technology progress among various countries and regions becoming larger . In the recent years, with the development of embedded, wearable and cyber-physical systems, a multitude of intelligent embedded systems has been implemented in personalized and preventive healthcare, such as application of home-based health monitoring services, implementation of telemedicine, progression of ambient assisted living, support of wellness services, empowerment of elder monitoring services, and further effort in high-risk patients management and quality of life enhancement (Tao et al., 2019; Tuli et al., 2019; Shaik et al., 2023).

## 10.2. Background

Healthcare technologies and devices have evolved increasingly to enable more personalized diagnostic and treatment capabilities. Technologies to accelerate healthcare are at different stages of maturity today, from exploration to early adoption phases. Examples of exploratory technologies include cloud-collocated algorithms for clinical decision support, predictive adaptive algorithms for diagnosis and treatment, and robotic-assisted intervention. These technologies are rapidly moving into the prototype and early adoption phases to augment tele-health and therapy delivery, accelerating the speed and investments toward a tech-enabled transformation of healthcare. Specialty tele-health delivery has gained added flexibility and support from augmentative technologies and devices that enable new features such as localization, motion monitoring, expansive fields of view, multimodal data representation, and portability. Robotic-assisted intervention, with increasingly specialized sensors and actuated affordances, has also gained an edge by supporting more procedures. These capabilities enable the decentralization of healthcare away from the hospital environment, transforming patients' homes into stages for remote procedures or appointments with specialists.

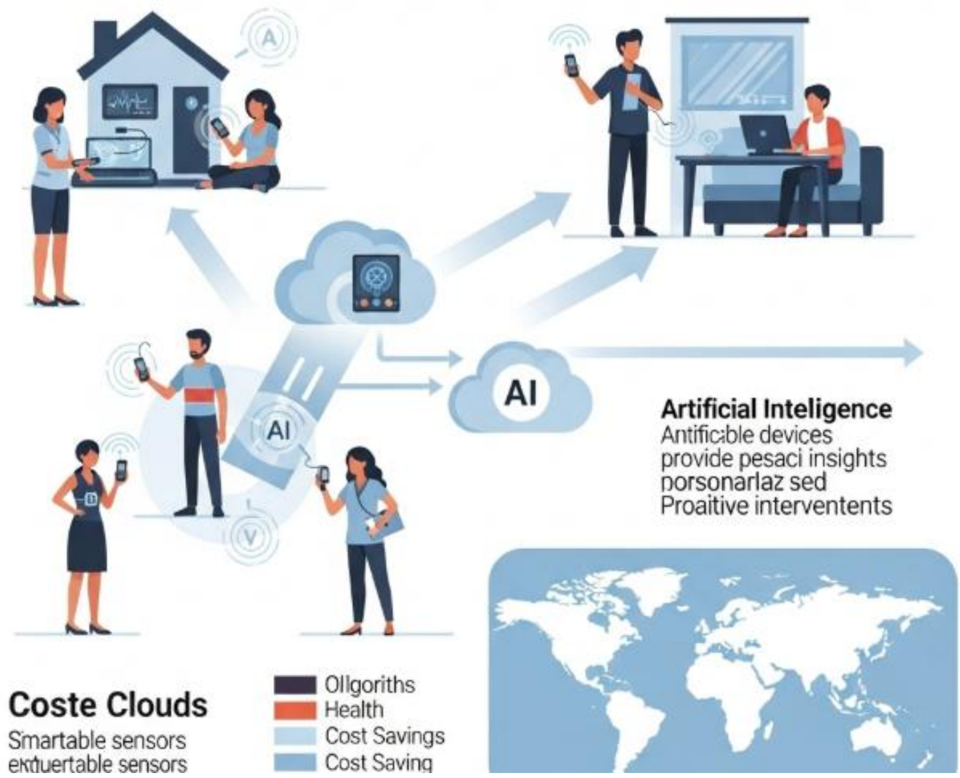


**Fig 10.1:** Personalized and Preventive Healthcare Through Intelligent

The appeal for decentralized and factorized healthcare delivery is twofold: the accessibility of clinical care for all under fortunate conditions, and the possibility to distribute preventive caregiving throughout a person's lifetime. However, all this tech-enabled transformation and improvement in accessibility to quality healthcare cannot overlook a huge disparity that exists today in cost and other factors: healthcare burnouts are surging. The potential solution to all of the above resides in embedded systems, which could be the driving element of the tech-enabled transformation of the future healthcare. Embedded systems with smart devices are rapidly advancing to bring healthcare digitization into society. Wearable sensor systems to assess heart physiology, ocular/perceptual neural systems for visual and fatigue monitoring, afferent and efferent artificial systems for muscular and movement engagement, and other wearable systems for multi-physiological monitoring are currently aiding clinical specialists with continuous monitoring for periodic checkups and ordering timely interventions. For invasive diagnostics such as fluid analysis, chip-enabled in vitro diagnostic devices have already been deployed for use in non-clinical environments like homes and workplaces.

### 10.2.1. Evolution of Healthcare Technologies

The ever-increasing lifestyle-related diseases and challenges in managing aging and disabled populations demand futuristic and personalized healthcare solutions. With the advent of advanced communication and information technologies, the healthcare landscape has also evolved drastically, and the healthcare market has grown tremendously. In the early days of healthcare, focus was on centralized diagnostic systems based on imaging technologies that required expensive equipment and skilled personnel, infrastructure, and were inaccessible to the rural and under-developed population of the world. Further innovations led to safer healthcare assisted by smart computerized and automated systems such as telemedicine services for remote diagnosis and surgery. With the explosion of the Internet age, ease of access to anything at any time and anywhere in the world has made the public more aware of their health. New tools for online healthcare services such as health and fitness blogs, health planning applications, and mobile based healthcare solutions have emerged. The latest decade has seen innovations in low-cost portable diagnostic devices, wearable sensors, and miniaturized intelligent embedded systems that aim to enable personalized medicine for a larger population, especially in the remote and rural areas.

The matured and ever-growing mobile market has also played a key role in the growth in the healthcare sector. From simple text messaging and computer based applications for setting up a tele-consultation session, the healthcare domain has spawned new, sophisticated mobile applications for managing appointments, self-health examination and guidance, real-time remote health monitoring and alerting, and mobile based tele-consultation services. The mobile phone today has become an inseparable aspect of our lives and its proliferation presents unique opportunities to make healthcare solutions accessible to the masses. Integrating the recent advancements in low-power nanosensor technology, intelligent embedded systems, and the ubiquitous mobile infrastructure, an efficient m-Health infrastructure can support remote monitoring and management of chronic diseases, personalized medicine, preventive healthcare, and timely intervention in case of emergencies.

### 10.2.2. Embedded Systems in Medicine

Recent advances in low-cost computer technology and wireless telecommunication systems have created new opportunities for designing specialized miniature electronic computers for a wide range of medical applications. Such microcomputers are now being utilized with great success to monitor various physiological parameters such as ECG, EEG, blood pressure, blood glucose, etc. These microcomputers are incorporated with embedded software to specialize them for an application. Embedded systems are optimized for specific input and output. The goal of these systems is to satisfy the constraints that are imposed by the physiologies being measured, the conditions under which the measurements are made, and by the requirements for precision, accuracy, cost, size, weight, and power consumption. Specifics also include cost constraints that dictate, for many applications at least, that the device be disposable, and that precision and accuracy criteria be less stringent than for traditional measurement techniques.

Many of the available commercial systems and those under development, and the applications for which they are designed, will be described. A summary of some of the more common body-worn, implantable, and telemedicine systems available, and a list of the what-measured and where-measured capabilities of some of these systems are given. Details of some of these specific systems will also be discussed, and the performance trade-offs associated with the choice of measurement modality will be explored. Additionally, some new innovative products, not usually found in this presentation, and some up and coming start-up companies will also be included in the overview.

## 10.3. Intelligent Embedded Systems

Embedded systems are electronic components and devices that perform a dedicated function but are not visible on the system's surface. For example, any smartphones, domestic appliances, or office automation devices that are programmed to accomplish a dedicated function are examples of embedded systems. Embedded systems can be used for application-specific tasks, such as automatic testing devices that can test a home appliance device's functionality or operation principle. Researchers have made efforts to improve the capacity of embedded systems for better dedication, low power consumption resilience, application-specific performance, and low cost. Therefore, embedded systems are becoming smaller in size and weight, and cost-effective. The trend shows that embedded systems will penetrate every aspect of our lives. Because of such importance, we choose the domain of intelligent embedded systems as part of the work.

Intelligent embedded systems are advanced versions of embedded systems for performing intelligent and dedicated functions. The advent of intelligent embedded systems has coincided with the era of artificial intelligence advancements. Increased computer memory, processing power, advancements in machine learning and deep networks, and innovation in data collection, storage, and extraction have facilitated the design and deployment of intelligent embedded systems. Intelligent embedded systems are intelligent extensions of our human capabilities. The knowledge models and supporting systems facilitate the intelligent systems with lower levels of autonomy. Based on the levels of autonomy, intelligent embedded systems are classified into autonomous systems, human-robot collaboration systems, tele-operated systems, remote suggesting systems, and tele-presence systems. Here, autonomy means acting or thinking without the influence of another agent. Present-day healthcare is well-fitted for the introduction of intelligent embedded systems.

### 10.3.1. Definition and Components

Intelligent Embedded Systems (IES) are technical systems resilient to environmental and operational variations that monitor local and remote physical assets in real time and provide useful support to their users for better decision making based on advanced data analytics. Indeed, IES can continuously process the data from various sensors to extract the essential information and infer the relevant context so that they can intelligently decide and execute what to do under the supervision of a remote data-centric system. IES covers a wide unmanned area with a decentralized operating structure if multiple systems run collaboratively. They can also be found in applications with on-site assisted human operation, where the IES offers valuable support to a smart user. The above definition points to three main components that are present in an IES: a seamless integration of intelligent software algorithms with the purpose of empowering the system autonomy and efficiency; a reliable and secure network core that connects local or remote components; and an embedded hardware architecture, which is the physical structure concerning sensors, actuators and computational units that run the intelligent software algorithms, interface with the network core and execute the actions driven by the decisions taken on the basis of the data coming from the sensors. The concept of intelligence embedded in the name of IES comes from the balance that needs to be struck between intelligence residing in the physical structure of the system and residing in the network segment connected to one or copious remote control centers. Emergent systems can be defined as IES when employing, for the onsite part, units and algorithms that guarantee a local coping with the unpredictable while facing time, localization, energy consumption and computational power constraints devoid of any assumption on the knowledge of the physical dynamics that govern the various situations and tasks.

### 10.3.2. Role in Healthcare

Intelligent embedded systems have found numerous applications for healthcare. Online sensor data and analysis can provide alerts, notifications, and self-healing mechanisms on patient's health. The wearable sensors for vital signs monitoring easily enable wireless connectivity via mobile phone or Bluetooth enabled small range connection. The wireless connectivity can enable remote consultation and regular connection with hospitals and doctors. Remote video or sensor based consultation during medical emergencies such as pneumonia, stroke, eye injuries, gastritis, low blood pressure, seizures, suicidal tendencies, blood vomiting, and inguinal hernia can be handled remotely by connecting with health system. Rural and semi-urban areas, which have limited health care and healthy infrastructure, can benefit from early diagnostics of these diseases using embedded systems monitored through wearable or implantable sensors.

Intelligent embedded systems can provide preventive healthcare such as behavior prediction, activity recognition, health risk assessment, disease progression modeling, selfless computing, and visual computing. The wearable embedded systems can bridge the gap between remote patient monitoring and healthcare resource optimization through wearable sensors and predictive analytics. Human behavior can predict seizure of epileptic patients, psychiatric disease, Parkinson's disease, PTSD, tremor and autonomic dysregulation, diabetic internal injury, panic and anxiety attack, and opiate intoxication. The person who suffers from heart attack, stroke, and Alzheimer's disease requires immediate medical care; hence, it is essential to identify that they are at risk. The health professional should be alerted about the person and send immediate medical assistance. People in age-group of 60-90 age group are at risk of Alzheimer's disease. The intelligent embedded systems can identify the diseases by keeping track of regular parameters and memory loss.

## 10.4. Personalized Healthcare

Concept and Importance Personalized healthcare is a concept that promotes the provision of medical care that focuses on the personal context of the patient; integrating their beliefs and preferences into the entire healthcare plan from prevention to cure. Personalized medicine is a more commonly used term that describes how genetic, epigenetic, and other biological and physiological factors are taken into account for diagnosis and treatment of diseases. These terms refer to the fact that the knowledge we have about each individual allows us to treat their diseases better and faster by eliminating any trial-and-error phases. Personalized medicine has brought about a paradigm shift in the entire healthcare field, particularly in the treatment of diseases such as cancer. A cornerstone of personalized medicine is the availability of genetic and epigenetic profiles of disease so that specific treatment can be tailored to specific subpopulations. Specific subgroups are defined based on genetic, epigenetic and exposome factors related to the individual. The subgroups evince a unique response to a treatment.

Technological Innovations The developments in semiconductor technology along with process chip manufacturing have enabled the implementation of sensor networks and systems that can be handheld and worn comfortably by individuals. The miniaturization of transistors has enabled large-scale integration of sensors, memories, and microprocessors on a single chip area that fit a few square mm. Smartphones and tablets embedded with thousands of sensors and massive processing power have exacerbated this trend. The mobility and wireless capabilities of these devices enable coding of personalized medicine applications on mobile platforms for easy access by patients and doctors for diagnosis and treatment. The widespread use of has enabled use of cloud-based services to make the costs associated with developing and maintaining these applications cost-effective; as a result, allowing mass access by individuals, caregivers, and healthcare providers. As millions of people embark on various diets and exercise regimens assisted by wearable devices, the idea of monitoring individual patients' health is increasingly being democratized through wireless devices.


**Fig 10.2:** Personalized Healthcare

### 10.4.1. Concept and Importance

Healthcare is one of the most crucial aspects of every individual's life. The concept of personalized healthcare is the one where no two human beings are treated the same way and every human body is understood based on its biology. The approach is to take into consideration every aspect of the person and study how it affects him and his needs rather than considering the person as an overall part of a group. The goal of healthcare services is to provide timely delivery of treatments for diseases. Although it has been considered for years that there is enough preventative capability in early warning and detection of diseases and the ability to tailor treatments is adequate for speeding up healing processes. Personalized healthcare considers further parameters associated with the treatment process in order to create a pleasant experience that people remember for years to come. It focuses on technological innovations to support customer-based methods keeping in view the various aspects of a person such as unique physiology and biochemical makeup that affect diagnosis and prevention of diseases instead of treating the diseases after having removed the manifestations.

Humans cannot control their biological makeup. But they can influence their living style such as in their environment, nutrition, activity, and interactions provided to maintain their health. Unlike a general doctor that monitors the patients only on their visits, the People 2.0 doctors periodically get unique personalized data of their patients, analyze it, and develop models for each one to understand the impact of lifestyle on their health. It helps the professionals deliver easy treatment suggestions at regular intervals even before the indications of diseases arrive. Personalized healthcare is key to opening the door to a wider world of options that enables individuals, as opposed to the society the person is part of, to choose their approach to health management.

### 10.4.2. Technological Innovations

For millions of people, monitoring their vital signs is becoming a normal daily procedure in order to obtain personalized health information. Cutting-edge technology enables people to perform measurements of heart rate, blood pressure, and other data regarding their health virtually at any time. The necessity of a more at-hand approach for daily health issues has risen the demand for wearable health devices and consumer electronics with health functionalities. Applications currently operating in this field can also perform remote monitoring for patients with chronic diseases in order to prevent complications and minimize the associated costs. Moreover, in the last decades, several technological innovations were introduced to facilitate this trend.

In an age where artificial intelligence and Augmented Reality are gaining a higher acceptance in everyday life, wearable health devices integrating these technologies will take personalized healthcare to another level. Wearable devices equipped with AI interpretation capabilities will enable users to obtain a more intuitive explanation of their health data obtained through sensors calculating biosignals, perhaps even through natural language interfaces. Furthermore, AR systems are becoming more versatile and affordable, thus enabling their integration into domains where they were still not widely adopted, such as telemedicine. Whether used on a smartphone display or implemented in smart glasses, AR is able to integrate the virtual and the real world, thus allowing communication and information sharing between doctors and patients.

### 10.4.3. Case Studies

A number of case studies are available demonstrating the utility of intelligent embedded systems for personalized healthcare. We report three examples to illustrate the broad applications and the capabilities. The first example is a home-care wireless body area network specifically designed for long-term elderly monitoring. This simple yet reliable system provides a comprehensive integration of different wireless technologies requiring a small set of sensors. The second example is a portable system for minimally invasive surgery that has been developed for laparoscopic surgery. The module transmits a telemetric signal and is powered directly by means of energy harvesting. The third example is a system for monitoring patients being treated for opioid dependence. The system that was developed is capable of performing continuous monitoring of the use of medications with psychoactive properties that are present in treatments in different concentrations.

We begin with a smart home wireless body area network for long-term elderly monitoring. The increase in the elderly population has highlighted the necessary requirement of long-term care. It is well established that for elderly people, their quality of life is greatly improved when they can remain in a home environment. WBAN technology allows continuous data monitoring of vital parameters. Considering the elderly population, they must be non-intrusive and simple to use. The goal of the presented WBAN is to develop an intelligent assistance system that is capable of monitoring freely living elderly patients and detecting unusual situations for alarms. The proposed patient monitor has the capability of measuring body, surrounding temperature, and ECG, acceleration, humidity, and gas concentrations, and it requires a low cost and a lower energy consumption. A PC will periodically collect the measurement data using wireless communication. The performed internal checks and external conditions allow the detection of altered states and the issuing of alarms.

### 10.5. Preventive Healthcare

Preventive Healthcare is the discipline of examining people for certain key indicators, autonomously estimating their probabilities of developing a certain disease over some time, and advising clients on suitable behavior that may reduce the probability of developing the disease. The goal of preventing diseases is motivating people to be more active, eat healthy, avoid stress, etc. How to motivate someone to be more active? It has been proposed that we should put advanced communication technology in our most used device every day: the smart phone. This opens the possibility for a health monitor in a place where technology is already present, and that we are with most of the time, connected to the rest of humanity, in a way that makes it easy for people to respond to this health stimulus. In future smartphones, one could integrate various health-related sensors, like accelerometers and gyroscopes, cameras, heart rate sensors, and thermometers. The phone would then perform all the signal processing on the system to detect anomalies. To provide reasonably precise probabilities for health risks during a visit, the wearable should monitor enough features for a long enough time, and select patterns that have previously been shown to forecast health problems.

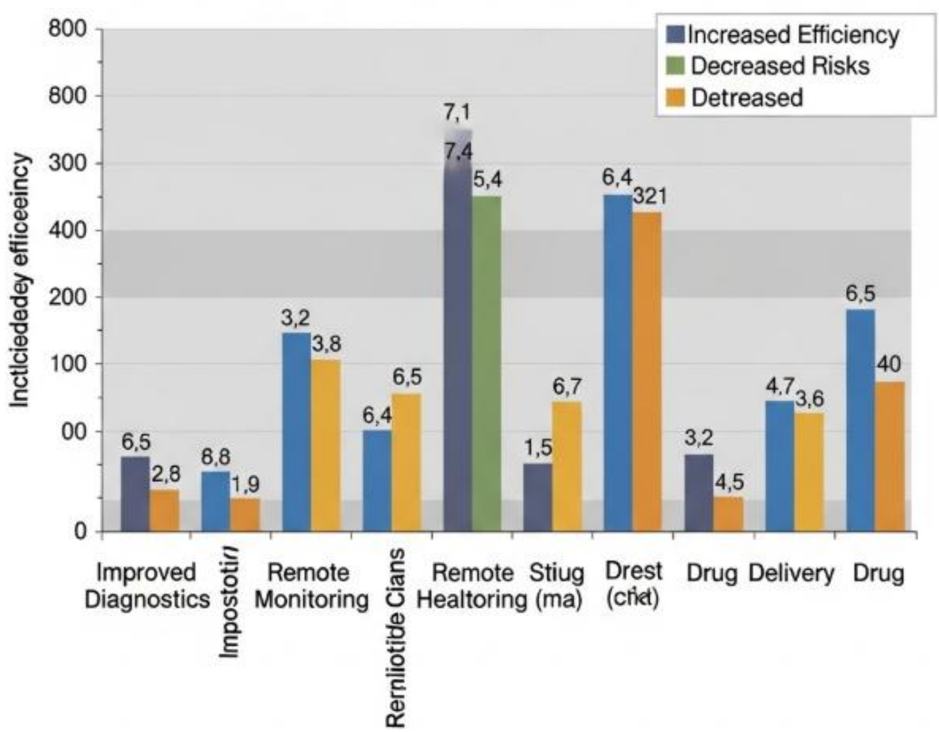


**Fig 10.3:** Enabling Personalized and Preventive Healthcare Through Intelligent Embedded Systems

The device would be applied to investigations of home monitoring of heart ailments, early indications of stroke, heart failure, skin cancer, and diabetes; as well as general health behavioral issues related to normal blood pressure, blood glucose, and cholesterol. Monitor behavior associated with epilepsy and Parkinson disease. How can we be more autonomous? Several embedded systems are proposed to help us monitor diabetes problems, measure insulin, and monitor hip activity with accelerometers to prevent falls. Embedded sensors also provide comfort to the elderly when they cannot be connected to a reasonable communication device, by using visible light.

### 10.5.1. Strategies and Approaches.

Preventive healthcare consists on avoid the rise of diseases being interventionist whenever possible, taking care of wellness and health using recurrent checks, evaluating each case and state in an individual way, collecting information constantly to define rules and drives personalized actions to obtain a state of health, closer to its maximum potential, whenever possible. It could be summarized in monitoring the patients constantly, intervening when its necessary, taking care of the risks, and treating the problems consistently. Intelligent embedded systems contribute with ubiquitous, cheap, and power-efficient devices that allow constant information collection and therapies adaptation. However, a huge difference exists between a system that store some data and made it clear at a request, and a embedded intelligent system that learns from the collected data, emits alerts, detects situations that can lead to a twist in health condition, and begins the therapy when is needed without the patient has to say anything. This embedded intelligent system should: (a) be capable of discovering correlations and consequences from actions taken, (b) learn and predict the effects of external changes and the patient own conditions that can be digitally represented, (c) assure that in the necessary actions to be taken in the home environment those interventions are simple, safe, easy to apply and supportive for patients and caregivers so they will be executed when needed, and (d) be trustable. Preventive healthcare strategies must combine digital data obtained from noninvasive sensors and wearable diagnostic devices, throughout the years for each individual, together with the periodic structure, behavioral and anthropometric data gathered by staffed health centers. Copies of DNA, genome data and other omics will appear without question in the personalized preventive model description for special populations, with risk factors in single, groups, and even combinations, obtaining better models of prevention and treatment of outbreaks but only when compliance can be confirmed.

### 10.5.2. Impact of Embedded Systems

The evolution of embedded systems equipped with sensors, and actuators, proprietary embedded software, artificial intelligence, and mobile connectivity have revolutionized device capabilities, opening up new ways to perform tasks. Often referred to as intelligent or smart devices, they can move, feel, see, sense, communicate, learn, and act. Such novel device systems are termed as Internet of Things sensor-embedded devices or simply IoT devices. These devices in their different forms are impacting each of the diverse sectors of our lives, such as education, finance, energy, transportation, commerce, and health, enriching and transforming their attributes. Intelligent embedded devices within the realms of universal healthcare are being developed and deployed for the personal wellness of all ages and gender. These devices gather specific informational signals, which are interpreted as general health conditions. The potential health issues are presented to users, health professionals, or diagnosing centers. The devices periodically monitor the specific measurable signals, helping diagnose symptoms and probable underlying chronic diseases based on abnormal signal patterns or trends of outcomes over time. IoT solutions in preventive healthcare can impact an individual's health and provide the following short-term and long-term benefits.

## 10.6. Data Management

The personalization of data generated by any system is only possible by building robust data management and analytical algorithms. Health systems generate massive amounts of data every day. Patient history and risk evaluation reports stored in databases are found to contain mostly programming codes. Also, generating and storing data in a format that requires several people having technical backgrounds working for many hours is not very useful. For enabling real-time algorithms predicting possible ailments, systems should create easy to search at risk reports in a time specific, systematic and easily accessible manner. Sensor data for tracking steps, heart rate, SpO2 levels etc. get generated in different data formats by different sensors from smart wearables. The format, size and collection frequency of the data streams differ from sensor to sensor. Intelligent systems for data collecting, storage and processing must be created.

Data is also needed for training predictive algorithms and is required to come from diverse population groups. Also, while generating surveillance, morbidity, and mortality databases and repositories, caretakers and researchers must place as much emphasis on privacy and confidentiality aspects as with the standard clinical data. Developing and deploying intelligent embedded technologies in health require careful consideration of ethical and regulatory issues especially in regard to ‘big data’. Intelligent systems that automatically process and detect possible ailments based on input data collected should also be fault tolerant and operate in a cold start scenario. Sleep as an uncomplicated disorder has been found to be a characteristic of some disorders and an indicator of other health issues, using predictive analytics to help recognize sleeping patterns can help towards recognizing other health issues.

### 10.6.1. Data Collection Techniques

Data management for personalized and preventive healthcare systems serves the dual purpose of enabling adequate healthcare services and simplifying the monitoring and tracking of collected information. Several fields of modern medicine demand precision healthcare methods based on the careful analysis of patient-related information to grant effective results in disease prevention and healthcare efficiency improvement. In this work, we focus on ambient and food sensing and on gesture recognition to demonstrate a perspective on data collection and management that may seem specific on first consideration, but that is broadened whenever necessary, elaborating in several other fields. First of all, we describe major data collection techniques and the requirements that these techniques must meet in order to be applied in practice. Secondly, we analyze the requirements of the data that need to be properly managed and that cannot be met by general-purpose data management components.

Medical applications demand high confidentiality standards that specific-purpose solutions must meet. Adequate techniques for private data collections are fundamental. Privacy can be secured by either non-disclosure of data or by utilizing efficient cryptographic techniques and/or confidential data representation. These may offer data protection from both data users and from the data manager. Also, the architecture must be designed in a way that the privacy and data management security requirements are met whatever the way data are collected, queried, visualized and pushed. Data is generated and collected in different ways and the data management component must efficiently handle the specificities of these data types and requirements. Indeed, different data capture techniques may be used for the patients' ambient data monitoring. Active tracking relies on patients' conscious involvement in providing information, describing their own disease pattern. Sometimes, patient response may be slow or inaccurate.

### 10.6.2. Data Privacy and Security

Several aspects define data management. Privacy and security are key properties in a healthcare system where sensitive data are handled. The risk of privacy invasions and security breaches arises first from the mere fact that data are collected. Almost all healthcare interactions produce raw data: body weight checks, blood tests, consultations, etc. But further data collection, and much more intrusive, usually occurs: genomics, electrophysiology, brain imaging, transcriptomics, etc. Second, the accumulation of a long record (especially the collection of genomic data) leads to stronger privacy concerns. Third, the value of such raw data in a problem-centric mode can be very high. Paid access to such data may be used to fund their collection on a pathogens-cum-reward basis. Data, when accessed in a privacy-compliant manner, may be accessible for secondary uses. Or they may be anonymized or pseudonymized for permissive public access. Third, those records are composed of very heterogeneous data types, and increasingly so. Fourth, pre-digested medicines data fusion is valorized through the emerging field of healthcare data science.

Data privacy can be defined as appropriate restrictions on the disclosure of information, while data security is the technical protection of the data throughout their life cycle. The legal constraints for these protections, on the life cycle of data, are still under definition. The General Data Protection Regulation of the European Union is a first attempt to relate data privacy to data management. The additional regulations of Europe are too recent to have a significant impact on digital health data management.

## 10.7. Machine Learning in Healthcare

To promote a healthy and balanced existence, in an attempt to allow for longer lives, healthcare systems must focus on prevention rather than curing diseases. This is only possible if smart embedded systems could help doctors and other healthcare practitioners with mining patients' data and discovering useful knowledge that could be acted upon to prevent diseases from occurring. Recent advancements in information technology and telemedicine have allowed for the monitoring of patients in the comfort of their home. E-Health platforms provide physicians with useful information on the vital signs of patients, such as blood pressure, glucose, temperature, and weight. Patients' monitoring was restricted to recording and displaying the information. Intelligent learning systems that could analyze the data and give assistance to the physician can help in risk assessment of chronic diseases or even predict the possibility of disease occurrence in the future. Over the last decade, many machine learning tools and techniques have been applied to several healthcare applications. In this chapter we overview several of them.

Machine Learning (ML) solutions have gained traction in various applications and services across industries due to the high degree of mathematical modeling capabilities of these solutions. Healthcare is an important and emerging area for ML applications since healthcare decisions are mostly complex, data-driven, and uncertain in nature. The application of AI is rapidly transforming the twenty-first-century healthcare space by making it more proactive, personalized, convenient, value-based, and preventive. Challenges and limitations of AI in Healthcare: Massive, high-dimensional, heterogeneous, and diverse data set containing complex nonlinear interrelation is essential for developing a reliable, accurate, practical, and robust AI solution in healthcare applications. To develop a practical AI solution for healthcare, it is often necessary to integrate data from multiple heterogeneous sources, including unstructured and diverse data, which poses another significant challenge.

### 10.7.1. Applications

Machine learning (ML) has found numerous applications in the healthcare domain. For example, ML techniques such as Neural Networks, k-Nearest Neighbors, and Random Forests have been used for diagnosis of Parkinson's disease, while ML methods have also been used to create diagnostic models for Parkinson's disease based on speech data by employing hidden Markov models and neural networks. Researchers also used the knee joint vibrations signals for the diagnosis of osteoarthritis (OA) by classifying the data using ML classifiers. Moreover, the economical aspect of conducting machine learning on the remote health monitoring of patients who have Parkinson's disease with the help of intelligent embedded systems has been discussed. Later, challenges and solutions in approaches for capturing and analyzing speech from distant microphones that are useful for ML and deep learning for health monitoring and detection problems have also been addressed.

In the context of monitoring older adults' health, ML models have been built and validated for assessment of frailty, prediction of chronic diseases, and for detection of other health problems related to memory or cognition. Moreover, the application of wearable technology on heart failure patients and the use of ML-based predictive models on remote monitoring of heart failure have been explored. Machine learning approaches for various health problems, including detection and prediction of nursing abnormalities, fall detection, estimation of fever or high temperature, and predicting the survival or death of association of sepsis, have also been developed and analyzed, while recent trends of Machine Learning in wearables, especially for the prediction or assessment of sleep activities with various Machine Learning methods, have been reviewed. Various wearable devices and Smartphone applications have been developed for different health problems, including physical activity monitoring of older adults, detection of hypertension, sports activity detection, emotion recognition, noise pollution monitoring and detection, and health monitoring of children and women.

### 10.7.2. Challenges and Limitations

The role of technology in healthcare has changed drastically over the past few years with the integration of artificial intelligence and machine learning algorithms. However, problems relating to ethics and trust in AI are not trivial and need to be investigated carefully. The most important security risk associated with AI is hacking. Hacking relates to adversarial attacks and unauthorized data access. Hackers can poison ML models with the objective of altering programmed architecture and injecting malware to affect real-world decisions. This modification of dataset inputs can lead an ML algorithm down the incorrect path. Security weaknesses associated with AI and ML can lead to a decrease in data privacy. For example, AI-based chatbots assisting hospital patients for unique queries can reveal private health records to hackers. Although existing cyber security systems can protect AI systems from hackers, the speed of hacking algorithms can outpace other ML models responsible for the protection.

Another challenge of ML in healthcare is the issue of algorithmic bias. Although bias in AI systems is a well-discussed topic, bias in CNN and other deep learning techniques has gone unnoticed. AI systems conduct healthcare procedures, but the data used to develop and train these systems often reflect current disparities within society. For example, the healthcare system has many effects of systemic racism and other social biases. These biases can be embedded within the multimodal data used to train healthcare ML systems. In order to counter algorithm bias, data scientists should analyze and mitigate bias within AI training datasets. Other bias counter strategies include data de-biasing, modeling de-biasing, and bias post-processing. Model validation and testing for bias are also very important.

## 10.8. Integration of Systems

Despite the degree of system autonomy or localization, there are advantages in assembling an integrated system-of-systems approach to enhance the performance of individual systems while also providing a basis for unprecedented capabilities for the overall system. For example, groups of individual systems can work together as an integrated team to: · Process more data faster and more effectively · Provide comprehensive patient overviews · Provide type 2 diabetes patients with an ecosystem covering all remote diabetes therapy-related tasks A smart healthcare environment should be designed with all the considered systems as parts of an integrated system-of-systems. This means that single-system design principles have to be lifted to support multi-system integration. The advantages of integration and cooperation have to be balanced with additional complexity issues from system design facing fast decreases in costs of individual systems combined with increases in cable and infrastructure costs. Together, these changes push towards increasing deployment of large numbers of small, cheap, and mobile embedded systems in our personal and corporate environments. These facts will also shape future system-of-systems designs with tightly integrated super devices and highly decentralized sensor networks working in concert with established large remote data management infrastructures. Furthermore, future systems will not only be employed in classical healthcare domains such as patient well-being post-encounter, but also in resulting services such as smart transportation and smart cities. Such systems will additionally have to face emerging integration requirements from cross-domain activity radiuses encapsulated by ever increasing server data analysis capabilities.

### 10.8.1. Interoperability Issues

Current technology has witnessed an explosion of diverse intelligent embedded systems over the past two decades. The wide range of applications ranges from smart sensors for environment surveillance, active RFID for logistics, or smart vehicle infrastructure for traffic control, to large-scale data collection for disaster management. A desire for building bigger and smarter national esoteric systems has been fueling the research on their integration. Networking has often been seen as the primary solution to the integration problem, which also gives rise to unreachable dreams of totally transparent integration.

However, these networking solutions do not solve the problems intrinsic to the diversity of various existing systems, their local high-level functionalities are not amenable to intelligent composition and external control, nor are their low level communication protocols mutually usable. They also often ignore the basic concepts of interoperability and scalability. We do not consider interoperability as a simple data exchange between one system and another. On the higher semantic level, we concern the composition of disparate local functions to generate an emergent global capability, and the remote management of geographically dispersed systems to achieve global objectives. Automatic situation evaluation and knowledge exchange are at the core of the interoperability needs. Integration and interoperability are usually addressed in the context of system engineering. The integration of distributed systems, infrastructure or sensor networks, although originally subject to the same principles, raised its own technical constraints: the scale issue and their immaturity.

### 10.8.2. Frameworks for Integration

The most critical components of the proposed architecture are: monitoring devices, signal processing components, analytics components, triggering logic components, media related components, interaction model related components, context and patient model related components, connection components, presentation components and personalization able to personalize any part of the platform. Components may be replicated in order to implement a redundancy model, load balance, multiple tasks, etc. Some of the previous components are similar to cause and effect. A relevant component is the presentation component as it interacts with any device capable of showing the alerts or supervised data. Though we are basically proposing a monolithic architecture composed of several modules we are enabling the proposal to make it scalable. Scale up being capable of attending a bigger number of patients or creating a more complex model, with more sensors or more specific alerts, and scale down to create lighter versions of the system. Capable of being run from a single computer connected to a web interface or to an Extranet, a situation with reduced user interaction or a complex interaction, including video, audio or sending/receiving multimedia messages, and being used for interactive education, relationships or life assistance, if possible. We also allow the possibility of integrating an arbitrary number of data sources and sinks, interactive or not, such as sensors, perception devices, biosignal acquisition and monitoring devices, etc.

Algorithm development and data storage and processing has been separated from the rest of the control triggering or treatment implementing logic, as it can be implemented in low processing and storage capabilities machines, for example small footprint cells at a Local Area Network level, an ADSL Level when triggering alerts or local/remote treatment steps. In order to check the feasibility of the concept an integrated and operational middleware has been implemented. It has been integrated in the development of a set of basic multimedia e-health applications, for mobile, LAN fixed and wireless Internet devices.

## 10.9. Conclusion

While medical science is currently undergoing a transformation, focused on patient-centricity and the involvement of artificial intelligence and intelligent, connected systems, it is expected that the elderly population's future health will rely on advanced technologies. Intelligent wearable systems supporting long-term monitoring using context-aware and adaptive automated systems will dominate the future healthcare scene, ensuring safety and satisfactory well-being. Cost-effective and efficient healthcare systems will shift the medical diagnosis and consultation practice from the hospital to the home. New-age intelligent embedded systems and their extensive and advanced use by healthcare professionals and related stakeholders will open up new business models based on data and services while answering the call of personalized and preventive medicine.

Ever-increasing societal and individual demands, expectations, and limitations related to current and future healthcare systems require innovative approaches based on the advanced use of technology. Personalized and preventive medicine represents a possible answer responding to such demands and limitations, unlocking new business models. Intelligent and integrated, data-driven, assistive embedded systems will allow such medicine to use both context-aware automation utilizing AI and machine learning and expert systems as well as novel-age assistive wearable sensors and systems for continuous monitoring of vital signs and the detection of atypical events or situations. However, the design of intelligent assistive embedded systems and related solutions responding to today's challenges and tomorrow's opportunities requires cross-domain collaborations at different levels and stages. This chapter presented an overview of today's possibilities, tomorrow's opportunities, and how to work collaboratively to reach the emphasis on business and adoption of intelligence and data-driven product services.

### 10.9.1. Future Trends

The future of self-repairing medical devices is bright. As technology advances and more people start to use smart health monitoring gadgets, the demand will only increase. While places like hospitals and urgent-care clinics might be least likely involved in self-repairing medical devices in the next few years, these inventions can inform a patient's condition or check for discrepancies before the person reaches the medical facility to lessen the burden on hospital workers and staff. Loans on some of the more costly medical devices could even be issued to an individual to ensure that they are monitored health-wise when needed. This system would also ensure that the patient returned the device when it was no longer necessary. This type of alert system might also benefit big businesses. Each year, corporations see thousands of dollars' worth of losses due to workers' health issues. Self-repairing medical devices can alert the worker to their health issues and, in turn, help the business save money dealing with workman's comp or lost revenue from unhealthy employees.

## References


Tao, H., Bhuiyan, M. Z. A., Abdalla, A. N., Hassan, M. M., Zain, J. M., & Hayajneh, T. (2019). Secured data collection with hardware-based ciphers for IoT-based healthcare. IEEE Internet of Things Journal, 6(1), 410–420. SpringerLink

Shaik, T., Tao, X., Higgins, N., Li, L., Gururajan, R., Zhou, X., & Acharya, U. R. (2023). Remote patient monitoring using artificial intelligence: Current state, applications, and challenges. arXiv preprint arXiv:2301.10009. arXiv

Tuli, S., Basumatary, N., Gill, S. S., Kahani, M., Arya, R. C., Wander, G. S., & Buyya, R. (2019). HealthFog: An ensemble deep learning based smart healthcare system for automatic diagnosis of heart diseases in integrated IoT and fog computing environments. arXiv preprint arXiv:1911.06633.

Shaik, T., Tao, X., Higgins, N., Li, L., Gururajan, R., Zhou, X., & Acharya, U. R. (2023). Remote patient monitoring using artificial intelligence: Current state, applications, and challenges. arXiv preprint arXiv:2301.10009. arXiv

Tuli, S., Basumatary, N., Gill, S. S., Kahani, M., Arya, R. C., Wander, G. S., & Buyya, R. (2019). HealthFog: An ensemble deep learning based smart healthcare system for automatic diagnosis of heart diseases in integrated IoT and fog computing environments. arXiv preprint arXiv:1911.06633. arXiv