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Impact of Healthcare Digitization: Systems Approach for Integrating Biosensor Devices and Electronic Health with Artificial Intelligence

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Abstract

Electronic health has revolutionized medical practices by seamlessly integrating digital tools and automated healthcare practices over recent years with the technological advancements of artificial intelligence. This multifaceted domain encompasses telemedicine, wearable technologies, electronic health records, and more, each with distinct subfields and innovative approaches. In this study, we provide a comprehensive overview of electronic health, delving into its diverse fields. We explore how artificial intelligence transforms medical imaging, informs clinical decisions, enables precision medicine, and empowers robot healthcare assistants. By shedding light on these hidden synergies, we aim to inspire researchers and practitioners to elevate their studies. Electronic health silently impacts our lives daily, and our work serves as a catalyst for recognizing its pervasive influence.

Keywords: Electronic health; mobile health; biosensors; precision medicine; artificial intelligence; patient monitoring; systems biology; bio-wearables .

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1. Introduction

Computer science is a huge field and artificial intelligence (AI) is a branch of that that focuses on computer intelligence and automated processes [1]. AI was first thought of in 1950, and it was mainly for manufacturing and design where many different manufacturing companies were making machines that could do what was thought only a human could. One of those machines was a robot arm that could function like a normal human's arm, and it was set on the factory line for the General Motors in 1961. In the late 1970s, AI was used to find its limits in the "AI Winters" which just consisted of many studies and creations using AI to see exactly how far we can push it. These studies consisted of resource computers at Rutgers University, a computer system at Stanford University, etc. In the late 1980s through mid '90s, AI had really progressed in Medicare. In 1986, DXplain (a decision support system) was introduced by the University of Massachusetts. This served as a medical textbook that provides detailed descriptions of diseases. Previous studies, such as the development of DXplain in 1986, have laid the groundwork for understanding AI's transformative potential in healthcare. These early efforts underscore AI's role in enhancing clinical decision-making and have paved the way for modern applications in precision medicine and telehealth. In the late 1990s reintroduced machine learning (ML) which greatly expanded medicine and set the stage for the modern era of AIM. Ever since AI was first thought of in 1950, there have been many different studies and projects to exercise its uses in healthcare. It's been almost 30 years since AI was thought of being used in healthcare and we have made some drastic improvements. Since the coming of Machine learning and deep learning, AI's uses have been expanded broadly and quickly in the field of electronic health (e-health) through biosensors, wearable technology, mobile health, etc. Because of this, there's more opportunity for personal medication and medicinal efficiency now than ever before.

AI has gone from something unheard of in the world of medication to something that could be the most valuable piece of technology ever and has been the core of what we now know as e-health [2]. E-health is a relatively new field of medicine that refers to the health services and information transmitted or enhanced through the use of the internet and related technologies. In a broader generalization, e-health characterizes the technical development of computers and leverages AI towards improving global healthcare by using information and communication technology [3]. AI can be combined with neural networks to produce a hybrid system that can ultimately cooperate with each other. The synergy created from this conjunction allows a system to extract raw data and use human-like reasoning and adaptation while still having the computing power of a top-of-the-line computer. In other words, AI can be combined with neural networks to create a system of artificial intelligence to do the work of humans and doctors while almost completely removing the percentage of human error [4]. Not only can AI be used more efficiently but there have been multiple events that give proof to this. The company IBM has been working on chatbots and more projects that take your symptoms and give you a result and prognosis quicker than any other doctor can and it has been very accurate [5]. The broad scope of possibilities of e-health and AI is sub-categorized into cancer research, drug development, diagnosis, medical imaging and more as shown in figure 1. . In this review, we dive into the intricate details of e-health in combination with AI tools. We discuss wearable wireless biosensors with the internet of things (IoT) in healthcare, systems requirements and specification decomposition for AI based biosensing methods, current applications of AI in healthcare, telemedicine, remote patient monitoring, mobile health (mHealth), wearable technologies, recent clinical applications, ethical considerations, challenges and the scope of future work leveraging AI with e-health capabilities for healthcare.

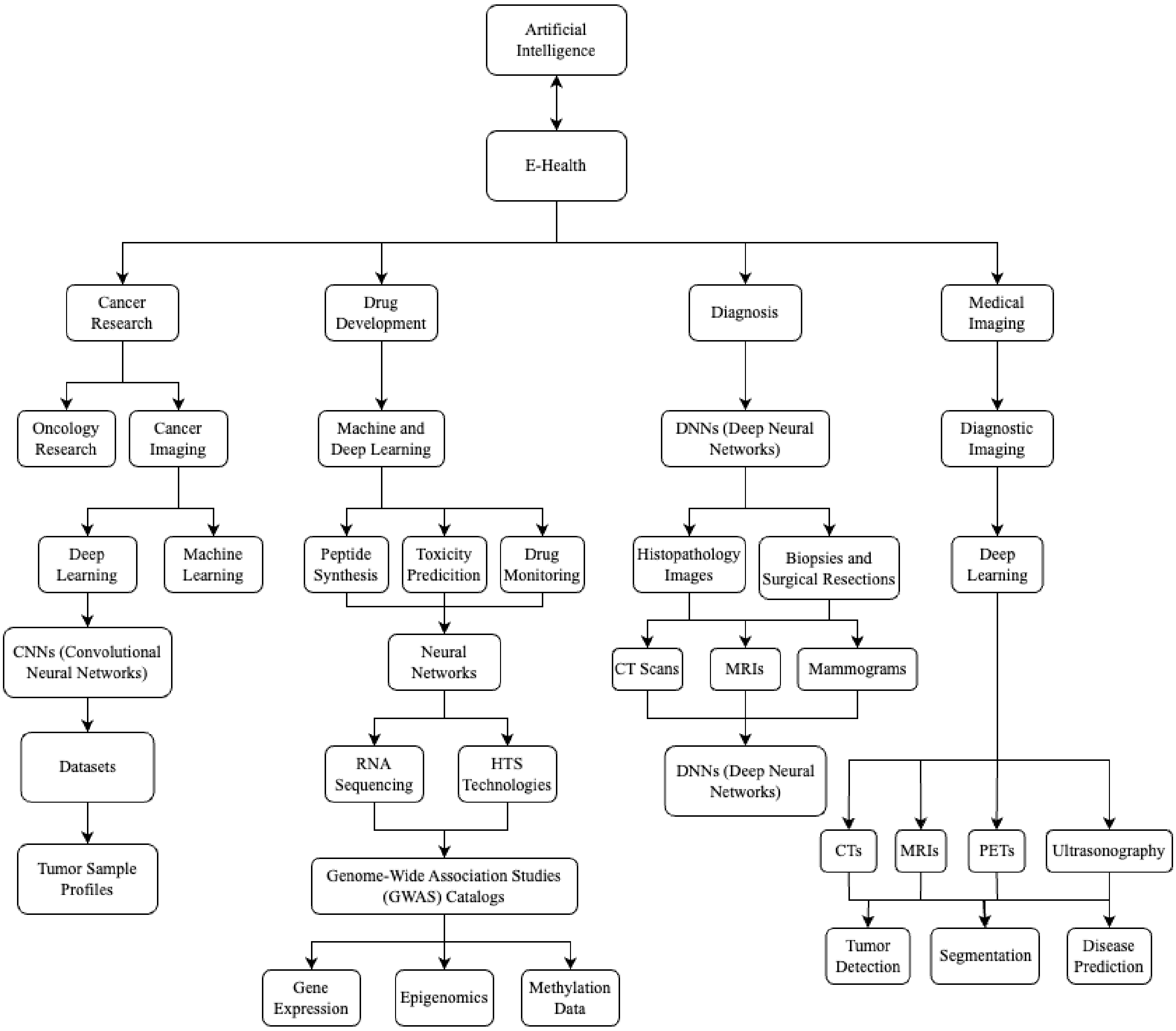

Figure 1: Classifications of e-health and artificial intelligence

2. Discussion

2.1. Wireless Biosensors and IoT in Healthcare

The emergence of intelligent biosensing to manage infectious diseases is an exciting intersection of AI and POC biosensing with possibilities offering rapid diagnosis, high sensitivity and most importantly accessible health assessment from a healthcare provider to patient level [6,7,8]. AI enhances the functionality of biosensors by improving data accuracy and processing speed. For instance, AI algorithms can analyze biosensor data in real-time, leading to faster and more accurate diagnostics. Successful implementations, such as AI-driven wearable biosensors for continuous glucose monitoring, have demonstrated significant improvements in patient outcomes by providing timely alerts and recommendations. POC biosensors being utilized as diagnostic tools such as screening cancer microenvironments and detection of microbial pathogens emphasize the affordable, specific, robust, and deliverable nature to end-users [9,10].

Introduced in 1980s by George Whitesides (Harvard University), Stephen Quake (Stanford University), and Andreas Manz (Twente University), microfluidics offered inkjet printing, DNA chips and lab-on-chip (LOC) technologies that shifted the paradigm of diagnostic towards POC biosensing [11]. More recently, wearable devices have intersected with microfluidics testing sample types such as sweat, tears and urine for real-time analysis using electrical sensing modalities [12,13]. In early-2024, this paved the way for AI-enhanced micro/nanorobots (MNRs) to collect precise information in a controlled manner combining sensing abilities of microfluidics [14]. Integrating an electromechanical MNR with AI, biosensing, and microfluidics would entail a complex multiplexed system as shown in figure 2. Although microfluidics offer an array of potential for growth, having precise accuracy on small-scale continues to be a problem leading to low resolution, cytotoxicity, sterilization and contamination risks [15]. To address these challenges, ongoing research is focusing on developing advanced materials and fabrication techniques to enhance the resolution and reduce cytotoxicity in microfluidic devices. Additionally, AI-driven noise filtering algorithms are being explored to improve signal-to-noise ratios, thereby increasing the reliability and robustness of biosensor readings.

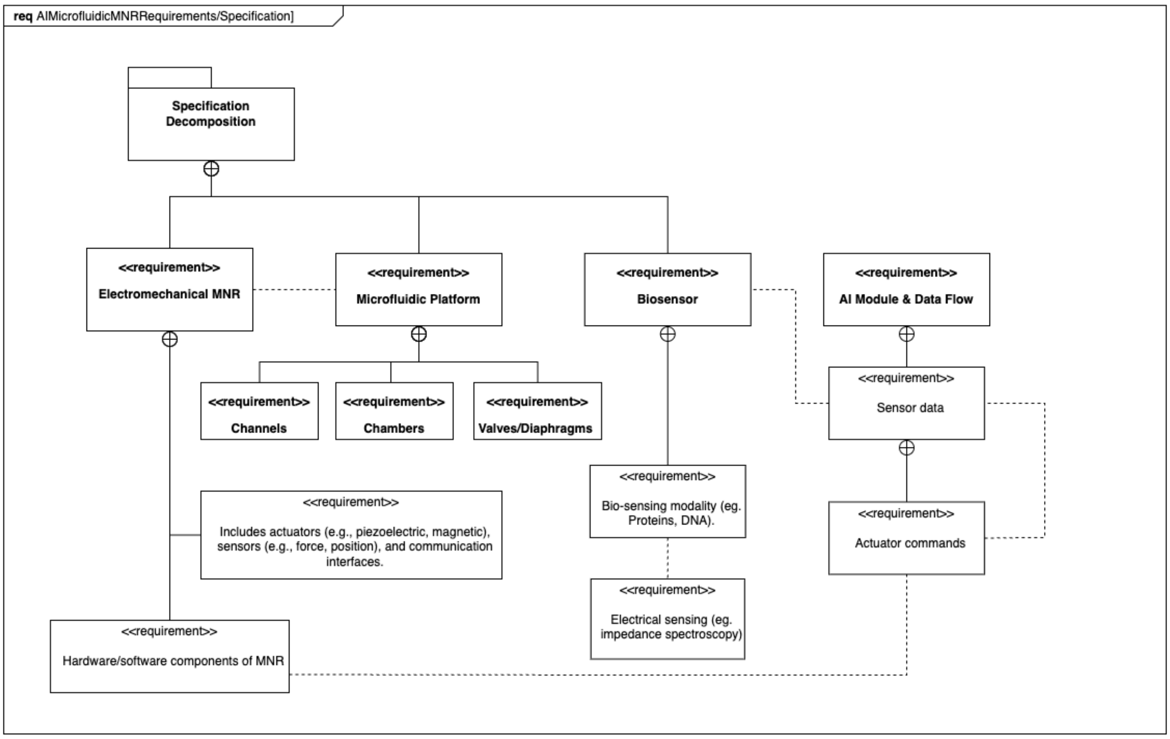

Figure 2: Systems requirements and specification decomposition for AI-MNR biosensing

Although optical biosensors were discovered for alcohol detection in 1975, it wasn't until 1980s that is was used for surface plasmon resonance (SPR) techniques, 1990s for fluorescence imaging, 2010s for wireless, real-time and remote patient monitoring, and beyond 2024 stepping into autonomous technology leveraging AI for smart-therapeutics [16,17]. Optical biosensors using CMOS-based spectrometers have the potential to be used in spectral analysis, scattering resonance and multiplexing reactions [18]. The opportunity to detect large molecules at low concentrations, combined with simultaneous detection of multiple analyte flavors make optional biosensors an ideal choice for efficiency for cell based molecular assays [19]. The cost associated with development poses a significant barrier towards limited practical applications and testing as shown in table 1 [17]. The integration with AI and optical monitoring offers opportunities for big-data analysis utilizing generative AI algorithms for data interpretation. Another aspect where AI could prove to be useful is assistance with noise filtering and drift correction to improve the signal-to-noise ratio providing a more sensitive and robust platform [20].

Table 1: Advancement of microfluidics during early development

Discovered	Type	Advantages	Applications	Limitations
1980s	Microfluidic-sample in sample out	Multiplexing options for nucleic acid purification, DNA amplification, automated assay development	Wearable devices	Low resolution, optical transparency, gas permeability.
1980s	Optical monitoring-remote optics biocognition	High sensitivity & specificity, RT-monitoring, multiplexing capability	Drug discovery & development, protein engineering, biomarkers, assays	Low spatial resolution, cost, complexity, safety

2.2. AI Applications in Healthcare

The emergence of intelligence; While electronic medical record (EMR) provides a quick electronic view of a patient's chart and electronic health record (EHR) provides an extensive electronic patient history, both are important pieces of information that are transmitted within a hospital network. Optimization and data analysis of information from EHRs has been made possible through natural language processing (NLP) and machine learning (ML). These implementations are often complex and expensive needing hardware capabilities. Furthermore, updates and transformations of patient information makes the transition more difficult. Building on past research, recent studies have demonstrated the efficacy of AI in optimizing EHR systems. For instance, NLP analytics have been shown to process large volumes of EHR data efficiently, as evidenced by studies analyzing up to 30,000 records per day. These findings highlight the evolution of AI's role in healthcare, from basic data management to sophisticated predictive analytics. [21]. Specific case studies have shown that AI-driven EHR systems can reduce administrative burdens on healthcare providers, allowing them to focus more on patient care. For example, AI tools have been used to automate the extraction of relevant clinical information, significantly decreasing the time required for data entry and retrieval.

AI uses past data and more information about your location and time to then predict what is going to happen next. In Mobile Health apps, mainly psychology apps, AI uses the past information you have given to then interpret what its next decision is. AI uses information about the user's state to determine when the user needs support and when he/she is responsive to interventions [22]. AI can also warn you if something is going on in your body or if there is expected to be a change in weather based on past data collected. Just like how AI can determine when the user needs support, it can determine what the weather will be like in a few hours (if there are any unexpected changes) or even if something's going on in your body based on past physical activity. AI can use past data on the weather to see if there are going to be any significant, unexpected changes and it can even track if something is going wrong in your body if you are stopping your physical activity quicker and quicker each day [23].

Cancer imaging and classification use what's called CNNs (Convolutional Neural Networks). CNNs use linear transformations to raw data to learn relevant features to the subject of study automatically. Since they are parts of DL, not ML this process is automatic. The datasets these CNNs use are obtained from the profiles of tumor samples from diverse and high-powered technology. AI can be used to obtain the profiles without human error and even quicker because of that high computing power so cancer research could be on a whole new level with the use of AI [24].

Like how AI can determine if you need any interventions, it can also determine what type of medicine you need or are recommended to take. Personalized medicine is more commonly known as precision medicine. Precision medicine can be best described as a healthcare movement involving a New Taxonomy of human disease based on molecular biology [25]. Precision medicine often allows doctors to discover and present information that could validate or change the directory of a medical decision. It gives a pharmacist information on the way a patient is headed regarding their treatment so that they can also go that way to further improve their health without needing to wait much longer after the doctor gives the green light [26]. Based on this AI can also send treatment recommendations based off of where your medicine is heading. All it does is take that data from finding the precision medicine and find a treatment that works with that in mind.

2.3. Telemedicine and Remote Patient Monitoring

Telemedicine is a great form of eHealth as it lets patients communicate with their doctors. Through Telemedicine, diagnostic devices are released that let the doctor see the diagnostic data in real-time, or later with some stored data. Many researchers are using these now and every one of them seems to say the devices are helpful in the hospital. However, before all of this growth, telemedicine used to be extinct. It first began in the 1920s as an idea, but the term was first coined in the 1970s. This term describes the use of telecommunication and IT in medicine to provide medical services across distances [27]. Historically, telemedicine has evolved from simple consultative services to comprehensive remote patient monitoring systems. Previous research has documented the gradual integration of AI into telemedicine, enhancing its capabilities and accessibility. Studies have shown that AI-driven telemedicine platforms can improve diagnostic accuracy and patient engagement, building on earlier telecommunication technologies. At the time, telemedicine was usually for consultative services, but now the uses of that have broadened as time has gone on. In 1994, Dr. Jane Preston of Texas Telemedicine and Dr. M. Row Schwarz, vice president of the American Medical Association, estimated over 100 telemedicine projects were being used and tested across the country. Not even a year later, that estimation skyrocketed to 200. The telemedicine we came to know only came about a decade ago, but the real growth happened more than 25 years ago during the production age which came to light what we know as telemedicine [28]. AI has significantly enhanced telemedicine by enabling automated triage and decision support systems. These systems can analyze patient data to prioritize cases and suggest potential diagnoses, thereby improving the efficiency and effectiveness of telehealth consultations.

Biosensors are used in many different fields of medicine, including disease identification, prevention, rehabilitation, etc. Many of these fields are used in what's called Remote Patient Monitoring. As the name says, Remote Patient Monitoring is the surveillance of patients through the use of cameras or sensors to give them their privacy. Biosensors can also be used to detect bacterial, pathogenic, and virus microorganisms [29]. These sensors detect chemicals without drawing blood spontaneously from the human body so the patient can be normal and rest while the sensors do all the work without drawing any blood from the patient. These sensors can also track chemicals from anywhere in the body. They can even track different body functions by altering the chemicals. People can get this information on an app and send it to their doctor, caretaker, or anyone they want to [30]. Because of the advancements in biosensors, they can be used to better the patient's health during Remote Patient Care.

Many Telemedicine projects and platforms have been produced and many of them use AI. Because of this, many studies are proving that telemedicine can be used to make patient health and technology better. McDaniel and his colleagues. discussed and assessed the reliability of a novel multifunctional pediatric tele-examination device. Built into the device is a digital stethoscope, a digital otoscope, and a tongue depressor to help offer a diagnosis of the heart, lungs, and ears in a pediatric setting. This model can create better quality images and sounds compared to standalone digital examination devices. It also resulted in lower rates of diagnostic failure [31]. This device was called the Tyto device and is now a global-trusted device for stay-at-home care for children. Carranza and his colleagues. developed a telepresence robot Akibot for remote medical consultation. The robot is equipped with a tailored screen tested for both Android and Windows, along with medical devices such as a stethoscope, otoscope, and ultrasound probe. Since most telecommunication patients are seated, the height of the robot was the height of the average person sitting down. The system is capable of running on LAN and VPN with an average delay of only 1.32 and 1.57 seconds across all commands [32]. Looking forward, AI-driven telemedicine platforms are expected to incorporate advanced features such as virtual reality for immersive consultations and AI chatbots for preliminary assessments, further expanding access to healthcare services

2.4. Mobile Health and Wearable Technologies

Another form of eHealth is mobile health. Mobile Health (mHealth) lets anybody have an app on their phone and they can open it anywhere at any time and they can get some information about their health at a glance. Not only can people look at their physical health, but newer psych apps are coming out to help people better their mental health. Psychiatric apps are letting people who already take psychiatric help obtain more or people who don't take psychiatric help start it. Even soldiers prefer to take psychiatric measures by iPhone rather than on paper or computer mainly because of the iPhone's portability [33]. The development of mHealth apps has been significantly influenced by earlier research on mobile technology and health informatics. Previous studies have demonstrated the potential of AI to personalize health interventions, as seen in the success of apps like HeartSteps. These studies provide a framework for understanding how AI can further enhance mHealth by delivering contextually relevant interventions. Many smartphone apps, especially those on self-help with stress reduction and wellness, and anxiety disorders have been adjusted so various patient groups benefit from them. One of them is called "Fear Fighter". It is a computer-guided self-exposure approach to treat phobia developed at the end of the last century. By using a computer-guided approach that makes most treatment suggestions, while still obtaining formidable results, both patients and doctors have benefited by saving time and enhancing healthcare efficiency [34]. Mobile health psychiatric apps gained traction during the COVID-19 pandemic from management of mental health disorders both for patients and healthcare professionals [35,36,37].

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