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AI-ML for Trending Biosensing Application

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ABSTRACT

Artificial intelligence, or AI, is an emerging discipline that draws on computer science to create algorithms and software that enable computers to perform jobs that would typically need highly cognitive human abilities. Modern medical sciences may perform better when using one or more of the AI subsets, such as machine learning (ML), deep learning (DL), fuzzy logic, traditional neural networks, and speech recognition. These innovative approaches have made it easier for people to engage in clinical diagnosis, medical imaging, and decision-making. The Internet of Medical Things (IOMT), an advanced bio-analytical instrument that combines software applications and network-connected biomedical devices to improve human health.

This study examines how artificial intelligence (AI) might enhance the functionality of point-of-care (POC) and IOMT devices used in state-of-the-art medical contexts like diabetes management, cancer diagnosis, and heart monitoring. This article also covers the use of AI in sophisticated robotic processes created for modern biological applications. This study critically and in-depth looks at how AI could enhance the functionality, detection precision, ability to make decisions, and assessment of related hazards of IOMT devices. This paper also covers the scientific, engineering, and economic potential for creating POC biomedical systems that are suited for next-generation intelligent healthcare using AI-based cloud-integrated customized IOMT devices.

Keywords*: wearables, point-of-care, smart sensors, internet of things in medicine, artificial intelligence.*

1. INTRODUCTION

A subset of the Internet of Things specifically created for use in the healthcare industry is called the Internet of Medical Things (IOMT). It involves networked medical equipment designed to remotely check on patients' health. In order to provide healthcare monitoring without continual human interaction, these IOMT devices—often referred to as healthcare IoT—use automation, sensor interfaces, and AI driven by machine learning. IOMT makes it easier for patients and healthcare professionals to communicate by enabling the safe gathering, handling, and transfer of medical data via secure networks. Wireless health monitoring is made possible by this technology, which can drastically lower the number of needless hospital stays and related medical expenses. Wearable technology for measuring health in real time, smart home healthcare solutions, and point-of-care (POC) equipment in clinical settings are just a few examples of the gadgets that fall under the umbrella of IOMT.

Sports watches, smart wristbands, electronic textiles, and gadgets with smartphone integration—all of which are wearable personal health monitoring devices—are essential components of this ecosystem. Practical uses for IOMT include telemedicine services like "tyropro" and on-demand medical exams. By monitoring the surroundings and keeping track of inadvertent falls, it also addresses the safety of senior folks by reducing chronic injuries. By giving customers access to automated detection tools and connected cloud solutions, this technology completely transforms traditional healthcare. It makes it simpler for rural inhabitants, physicians, and patients to obtain high-quality healthcare services. POC gadgets with internet connectivity, such as thermometers, glucometers, ECG readers, and ultrasonography, enable consumers to keep a closer eye on their health.

Additionally, by permitting direct contact between patients and clinicians and facilitating modifications to therapies like insulin levels, IOMT supports better healthcare management. Even "smart beds" that change positions in response to patient needs are being introduced by cutting-edge healthcare facilities. Through IOMT, traditional home healthcare services are also changing. Medication schedule notifications are sent to patients and clinicians automatically via smart home medication dispensers that upload patient medical history data to the cloud. The need for healthcare systems is rising due to factors like urbanization, industrial adaptation, population growth, and technology improvements.

This paper emphasizes the role of IOMT-integrated devices, including cellphones, sensors, and actuators, in enabling routine healthcare monitoring to meet these evolving needs.

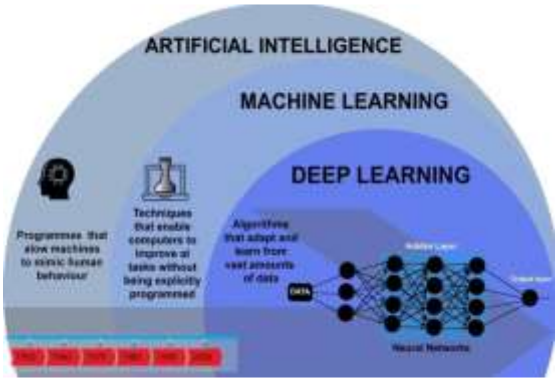

Figure 1: Schematic representation of AI, ML and DL

2. ROLE OF NANOTECHNOLOGY AND IOMT IN HEALTHCARE

The convergence of artificial intelligence (AI) and nanotechnology is transforming healthcare, raising the standard of medical care across a range of specialties. The precision and shrinking capabilities of nanotechnology and the analytical capability of AI combine to form a potent combo. This synergy is essential for developing innovative healthcare solutions like nanomedicine and nanorobotics. These advancements bridge the gap between nanotechnology and the Internet of Medical Things (IOMT), enabling state-of-the-art medical applications. Wearable, continuous monitoring devices with nano-enabled sensors are critical to this ecosystem. These sensors continuously monitor physiological data, providing a helpful tool for diagnosis and prognosis. Large clinical datasets must be employed for AI in order to ensure the dependability of these monitoring systems.

Nanomaterials known for their electrical properties and biocompatibility, such as carbon nanotubes and graphene, are crucial for bio signal monitoring. The creation of wearable technology that seamlessly integrates with the skin is made feasible by them. One extensively studied nanomaterial, graphene, is used in biosensors and human sensory process simulation, among other biomedical uses. Its large surface area makes the use of extremely sensitive biosensing devices possible. Furthermore, graphene's mechanical properties enable the creation of sensors for uses including tactile sensing, gas detection, and electronic noses (e-noses). Through AI-driven machine learning, these sensors' accuracy and utility are increased.

The use of artificial intelligence enhances efficiency and tailoring of medication delivery and diagnostics by predicting the behaviour of nanomaterials and their interactions with biological systems. AI models predict cytotoxicity, porosity across biological barriers such as the blood-brain barrier, and the effectiveness of pharmaceutical encapsulation. These projections serve as a roadmap for developing safer and more potent nanomedicines. Furthermore, chemoreceptive sensors based on gold nanoparticles and AI are employed to identify abnormalities like preeclampsia. AI also has an impact on the development and synthesis of novel nanomaterials, such as covalent organic frameworks (COFs) and metal-organic frameworks (MOFs), which are used in electrochemical and gas sensing.

Figure 2: Smart features of Machine Learning for healthcare domain

(Source: Significance of machine learning in healthcare: Features, pillars and applications)

3. ROLE OF AI IN DIABETES MELLITUS AND CANCER MANAGEMENT

Elevated blood glucose levels resulting from insufficient or ineffective insulin administration are a common symptom of chronic diabetes. Two helpful technologies for controlling diabetes are machine learning and artificial intelligence (AI). They have the potential to predict the onset of diabetes, improve glucose monitoring using state-of-the-art instruments, and assist in the proper detection of diabetic retinopathy. Constant monitoring of blood sugar levels is made possible by the FDA-approved wearable device called a continuous glucose monitor (CGM), which enhances diabetes treatment. In contrast, uncontrolled cell growth and metastasis to other body parts are indicative of cancer. AI is transforming research, diagnosis, and care, and it has a significant influence on cancer management. AI assists in the detection of cancer and also finds new therapeutic targets, facilitates the development of personalized cancer treatments, and accelerates the drug discovery procedure.

People with diabetes face several challenges, particularly those who reside in impoverished areas. These difficulties include a lack of access to medications, a lack of information, and barriers to using healthcare systems, all of which increase the risk of complications and lead to poor control of diabetes. Furthermore, after receiving cancer therapy, those with diabetes or hyperglycemia had higher rates of death and recurrence, as well as a greater likelihood of developing a number of other malignancies.

Implantable devices and artificial intelligence are revolutionizing the way diabetes and cancer are managed. While wearable technology—like CGMs—allows for constant monitoring in the treatment of diabetes, artificial intelligence (AI) offers personalized cancer treatments and early diagnosis. While challenges persist, especially for marginalized populations, wearable technology and AI integration hold promise for enhancing outcomes for people suffering from such ailments.

4. AI-SUPPORTED CARDIAC MONITORING

The global death toll from cardiovascular diseases (CVD) is expected to reach 18 million in 2019, with low- and middle-income nations being disproportionately affected. The risk of CVD is heightened by genetic factors, lifestyle modifications, and elevated stress. Heart failure, heart attacks, and cardiac arrhythmias are just a few of the CVDs that can impair the heart's ability to pump blood, making the use of monitoring methods like electrocardiograms (ECG), stress testing, and biomarker profiling necessary. A vital indicator in predicting cardiac illnesses is the ECG in particular, which provides information about the structure and function of the heart. Single-channel ECG recorders are now more accurate in detecting variations in heartbeat, even though they call for a lot of data.

ECG data has been utilized to identify arrhythmias and other cardiac-related problems using machine learning (ML)-based algorithms, made possible by advancements in cloud computing and data processing tools. A noteworthy contribution by Kachuee et al. was the development of a deep learning technique for ECG analysis, which demonstrated improved identification accuracy for cardiac abnormalities. Additionally becoming more popular are photoplethysmograph (PPG) sensors found in smartwatches and smartphones as means of detecting AF. The WATCH AF study showed that smartwatches can identify AF more accurately than cardiologist interpretations when using PPG data. ECG validation is still necessary in cases of suspected AF, nevertheless.

Further, machine learning frameworks have been used for examining individual genomes and electronic health records (EHRs) for health insights. Employing a personalized approach to healthcare, Li et al. identified patterns and mutations associated with abdominal aortic aneurysms (AAA) using high-coverage whole-genome sequencing (WGS) and hierarchical estimate from agnostic learning (HEAL). This innovative approach is a prime illustration of the potential applications of genomics and machine learning for illness and prevention.

Figure 3: Application of Artificial Intelligence in Cardiology

(Source: Using AI to Leverage Healthcare Data to Inform Routine Care)

5. ROLE OF AI IN SURGERY

Due to their ability to provide real-time monitoring and feedback, wireless sensor networks (WSNs) are critical to the medical field. They consist of scattered sensors that collect and relay environmental data, including sound, temperature, and humidity, to a central hub. Video monitoring and industrial automation are just two of the uses for WSNs in smart environments. Surgery relies heavily on artificial intelligence (AI), which aids in disease detection, preoperative planning, intraoperative support, robots, training, and other areas. But obtaining data for AI training raises moral concerns about patient privacy. The need for AI-enabled WSNs is anticipated to grow in the future due to possible applications in spectrum management, security, underwater acoustic sensors, and cognitive sensing. Ultimately, surgical learning powered by AI has the potential to enhance patient care by increasing the quality and productivity of surgical training while taking moral considerations into account.

6. THE ROLE OF AI IN ESTABLISHING A SMART SENSOR NETWORK

Urban planning, industrial automation, healthcare, and environmental monitoring are merely some of the many applications that artificial intelligence (AI) has an impact on. AI is essential to the growth and operation of smart sensor networks in the Internet of Things (IoT) space. The benefits of AI are countless. It makes it possible to quickly process and analyze large amounts of sensor data, including essential tasks like feature extraction, noise reduction, and data cleaning in order to obtain insightful information. Applications such as predictive maintenance in industrial settings are made possible by AI-driven machine learning models that are trained on existing sensor data to forecast future events or anomalies. Identifying security breaches, equipment problems, or environmental anomalies requires constant monitoring and anomaly detection using AI algorithms.

AI likewise enhances the way sensor nodes react in real time, which increases energy efficiency and prolongs the life of sensor nodes that run on batteries. Through the integration of data from various sensors, artificial intelligence (AI) offers a comprehensive perspective of the surroundings, enabling well-informed decision-making for tasks like traffic control in smart cities. AI also improves sensor network security by identifying and thwarting cyberthreats and facilitating user-friendly interfaces via chatbots that leverage AI to make data easier to obtain and understand. To summarize, artificial intelligence (AI) enables smart sensor networks to function efficiently, rapidly, and with exceptional decision-making powers by processing, evaluating, and drawing valuable insights from sensor data. This opens up a plethora of applications in various domains.

7. CHALLENGE AND FUTURE PROSPECTS

Artificial Intelligence (AI) and machine learning (ML) are enabling significant breakthroughs in medical fields, such as diabetes management, cardiac arrhythmia monitoring, and surgical support. They help with data analysis, improve decision-making, and address complex sensor data in an efficient manner. AI/ML techniques' ability to extract pertinent insights from loud or low-resolution data sources improves the overall efficiency of Internet of Medical Things (IOMT) devices.

All IOMT equipment used in modern healthcare must be connected in order for it to function. These devices' capacity to establish both unidirectional and bidirectional connections allows for the smooth exchange of information between patients and medical providers. For signal conditioning, analogue front ends (AFEs) are used instead of bulk electronics, and microcontrollers are coupled to AFEs via communication protocols including I2C, SPI, and UART. Connecting IOMT devices to central hubs is mostly accomplished through Wi-Fi and Bluetooth communication methods. Short-range data transfer in settings like operating rooms and intensive care units is suitable for Bluetooth, even though corporate Wi-Fi provides better security and speed. Given that they are so portable, smartphones have a significant influence on IOMT device applications. Through enabling online communication between medical professionals and patients via mobile gadgets, access to healthcare is elevated. The mobile healthcare sector must, however, resolve privacy and security concerns.

The future success of IOMT depends on the integration of advanced AI/ML technologies. AI-based IOMT devices are predicted to have the following characteristics: low power consumption, miniaturization, high sensitivity, industrial-grade production, affordability, and multi-level functionality. Improvements in microelectronics and nanotechnology will support these developments, facilitating access to high-quality healthcare.

8. CONCLUSIONS AND VIEWPOINT

The present study highlights the advancements in AI-enabled Internet of Medical Things (IOMT) devices, with the aim of optimizing biosensing for disease management. An important focus is on nanotechnology integration, which paves the way for the development of innovative biomedical devices such as e-skin, e-nose, and e-textiles that work with AI and IOMT. These integrated devices are critical to critical medical applications that involve cancer monitoring, diabetes control, heart monitoring, and surgery.

Artificial intelligence has been a huge help to the medical professions of cardiac electrophysiology, surgery (including the Da Vinci surgical system), personalized diabetes, and cancer therapy. The data's accuracy makes it possible to predict illnesses in their early stages and measure risk. Machine learning, support vector machines (SVM), and neural networks (NN) are a few of the various AI subcategories that are widely employed in the healthcare sector. In spite of tremendous progress, heterogeneity, interconnectedness, and complex data management continue to be challenges for AI. AI is continually advancing and demonstrating its superiority, even though it cannot yet fully replace all medical jobs. In order to promote disease prevention and treatment in a personalized manner, the project supports multidisciplinary research integrating IOMT, AI, and nano sensing.

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