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AI-ML for Trending Biosensing Application

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ABSTRACT

Artificial intelligence (AI) is a modern approach based on computer science that develops algorithms and programmes to make computers intelligent and successful at doing tasks that traditionally require a high level of human cognition. One or more of the AI subsets, including machine learning (ML), deep learning (DL), classic neural networks, fuzzy logic, and speech recognition, may improve the performance of modern medical sciences. It is now simpler for humans to participate in clinical diagnostics, medical imaging, and decision-making thanks to these creative solutions. In the same time frame, the Internet of Medical Things (IOMT), a next-generation bio-analytical tool that combines network-connected biomedical equipment with software applications for enhancing human health

This study discusses how AI may improve the performance of point-of-care (POC) and IOMT devices used in cutting-edge healthcare settings such as heart monitoring, cancer diagnosis, and diabetes control. The use of AI in advanced robotic processes developed for cutting-edge biological applications is also covered in this article. This study thoroughly and critically examines how AI might improve the functioning, detection accuracy, decision-making capacity, and evaluation of associated risks of IOMT devices. The scientific, engineering, and commercial potential for developing efficient POC biomedical systems suitable for next-generation intelligent healthcare employing AI-based cloud-integrated individualized IOMT devices are also covered in this study.

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

1. INTRODUCTION

The Internet of Medical Things (IOMT) is a specialized branch of IoT technology designed for healthcare applications. It involves interconnected medical devices aimed at remotely monitoring patient well-being. These IOMT devices, often referred to as healthcare IoT, employ automation, sensor interfaces, and AI powered by machine learning to offer healthcare monitoring without constant human intervention. IOMT facilitates the connection between patients and healthcare providers, allowing the secure collection, processing, and transmission of medical data over protected networks. This technology introduces wireless health monitoring, which can significantly reduce unnecessary hospital stays and associated healthcare costs. The scope of IOMT includes various devices, such as point-of-care (POC) equipment in clinical settings, wearable devices for real-time health tracking, and smart home healthcare solutions. Wearable personal health monitoring devices like smart wristbands, electronic textiles, smartphone-integrated gadgets, and sports watches play a vital role in this ecosystem. IOMT has practical applications, such as on-demand medical examinations and telemedicine services like "tyropro." It also addresses the safety of senior citizens by tracking unintentional falls and preventing chronic injuries through environment monitoring. This technology revolutionizes traditional healthcare by providing consumers with integrated cloud solutions and automated detection tools. It enables easier access to high-quality healthcare services for patients, doctors, and rural residents. Internet-connected POC devices like ultrasonography, thermometers, glucometers, and ECG readers empower users to monitor their health more effectively.

Furthermore, IOMT promotes improved healthcare management by facilitating adjustments to treatments like insulin dosages and enabling direct communication between patients and clinicians. Advanced healthcare facilities have even started implementing "smart beds" that adjust their position based on patient needs. Traditional home healthcare services are also evolving through IOMT. Smart home medication dispensers automatically upload patient medical history data to the cloud, notifying clinicians and patients about medication schedules. The ever-growing population, technological advancements, industrial adaptability, and urbanization are driving increased demand for healthcare systems. This paper emphasizes the role of IOMT-integrated devices, including cellphones, sensors, and actuators, in enabling routine healthcare monitoring to meet these evolving needs.

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

Artificial Intelligence (AI) plays a pivotal role in the development and functionality of smart sensor networks within the Internet of Things (IoT) landscape, impacting a wide array of applications such as smart cities, industrial automation, healthcare, and environmental monitoring. AI's contribution is multifaceted. It enables the swift processing and analysis of massive volumes of sensor data, encompassing critical tasks like data cleaning, noise reduction, and feature extraction to derive meaningful insights. AI-driven machine learning models are trained on historical sensor data to predict future events or anomalies, allowing for applications like predictive maintenance in industrial settings. Continuous monitoring and anomaly detection through AI algorithms are vital for identifying security breaches, equipment issues, or environmental irregularities.

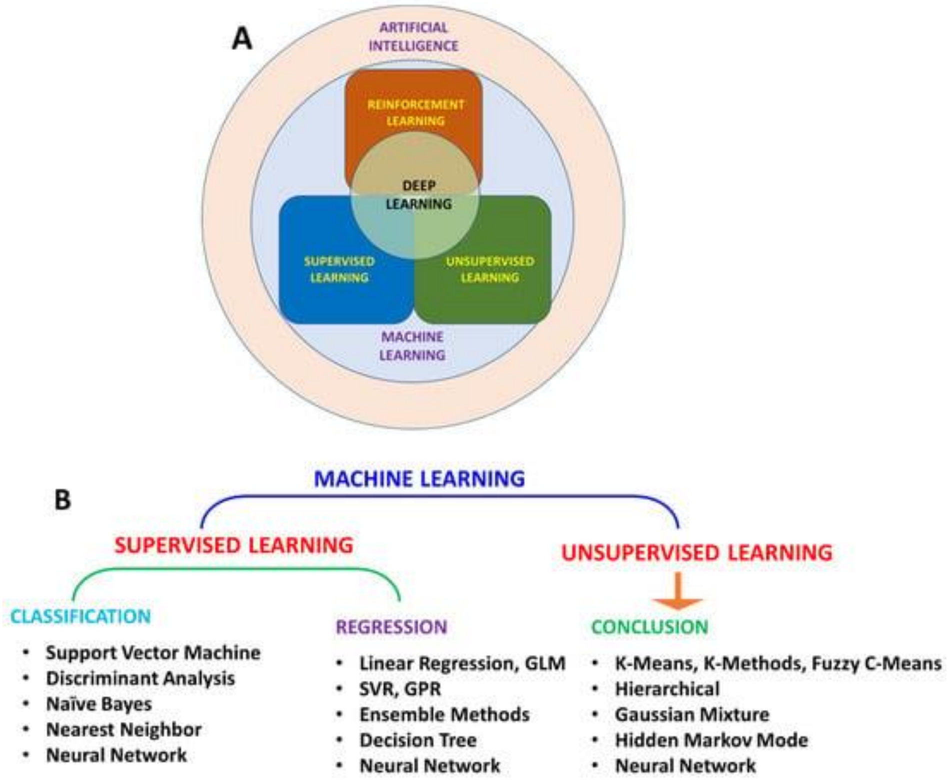

Figure 1: Schematic representation of relation between AI, ML, and DL; classification of ML algorithm.

(**Source**: Artificial Intelligence (AI) and Internet of Medical Things (IoMT) Assisted Biomedical Systems for Intelligent Healthcare)

Additionally, AI optimizes real-time responses to sensor inputs, enhancing energy efficiency, and extending the operational life of battery-powered sensor nodes. By amalgamating data from diverse sensors, AI presents a more holistic view of the environment, facilitating informed decision-making, such as traffic management in smart cities. Furthermore, AI strengthens sensor network security, detecting and mitigating cyberthreats while providing user-friendly interfaces through AI-powered chatbots, making data more accessible and comprehensible. In conclusion, AI's role in processing, analyzing, and deriving valuable conclusions from sensor data empowers smart sensor networks to operate effectively, adaptably, and with superior decision-making capabilities, ushering in a wide range of applications across multiple fields.

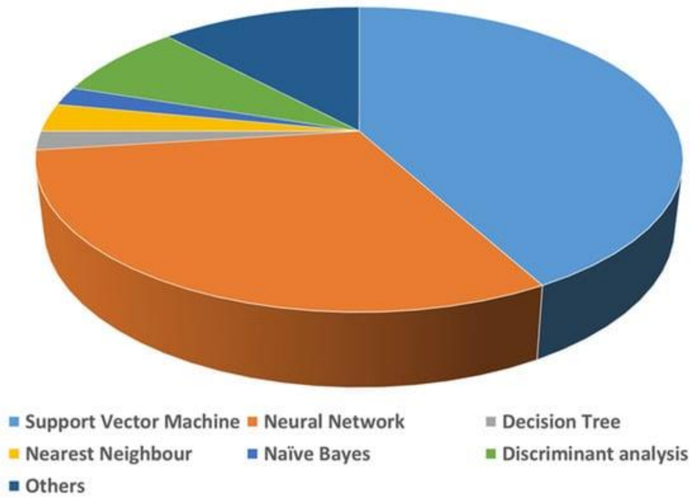

Figure 2: Use of various AI methods in medical applications.

(**Source:** Conflicting Knowledge Paradigms: Competence Discourse and Disciplinary Reality in Social Sciences Teaching)

3. ROLE OF NANOTECHNOLOGY AND IOMT IN HEALTHCARE

Healthcare is undergoing a transformation as a result of the confluence of nanotechnology and artificial intelligence (AI), which is improving the caliber of medical services in a variety of fields. A powerful combination is created by the accuracy and shrinking skills of nanotechnology and the analytical strength of AI. The creation of cutting-edge healthcare solutions, such as nanomedicine and nanorobotics, depends on this synergy. These developments enable cutting-edge medical applications by bridging the gap between nanotechnology and the Internet of Medical Things (IOMT). This ecosystem heavily relies on wearable continuous monitoring devices with nano-enabled sensors. These sensors track physiological data continually, offering a useful resource for prognosis and diagnosis. To guarantee the dependability of these monitoring systems, significant clinical datasets must be used for AI analysis and training.

Moreover, nanomaterials like graphene and carbon nanotubes, recognized for their electrical characteristics and biocompatibility, are essential for bio signal monitoring. They make it possible to create wearable gadgets that meld perfectly with the skin. A highly researched nanomaterial like graphene, for instance, is employed in a range of biomedical applications, from biosensors to simulating human sensory processes. Due to its vast surface area, very sensitive biosensing equipment is possible. Additionally, the mechanical characteristics of graphene allow for the development of sensors for applications such as electronic noses (e-noses), gas detection, and tactile sensing. The accuracy and usefulness of these sensors are improved using AI-driven machine learning.

Artificial intelligence helps forecast the behavior of nanomaterials and how they interact with biological systems, improving the effectiveness and customization of medicine administration and diagnostics. The efficiency of medication encapsulation as well as cytotoxicity and permeability across biological barriers like the blood-brain barrier are all predicted by AI models. The creation of safer and more effective nanomedicines is guided by these predictions. Additionally, AI-driven gold nanoparticle-based chemoreceptive sensors are used to detect diseases like preeclampsia. The discovery and creation of new nanomaterials, such metal-organic frameworks (MOFs) and covalent organic frameworks (COFs), with uses in gas sensing and electrochemical sensing, are also influenced by AI.

4. AI-SUPPORTED CARDIAC MONITORING

Around 18 million deaths worldwide will be attributed to cardiovascular diseases (CVD) in 2019, with low- and middle-income countries being particularly hard hit. Genetic factors, alterations in lifestyle, and increased stress all raise the risk of CVD. The heart's capacity to pump blood can be compromised by a number of CVDs, including heart failure, heart attacks, and cardiac arrhythmias, necessitating the use of monitoring techniques including electrocardiograms (ECG), stress testing, and biomarker profiling. The ECG in particular, by revealing information about the anatomy and operation of the heart, plays a critical role in predicting cardiac diseases. Despite being data-intensive, modern single-channel ECG recorders have been improved to precisely identify heartbeat fluctuations.

With the assistance of improvements in cloud computing and data analysis tools, machine learning (ML)-based algorithms have been used to identify arrhythmias and other cardiac-related disorders using ECG data. Kachuee et al.'s significant contribution was the introduction of a deep learning method for ECG analysis, which showed higher accuracy in the identification of cardiac irregularities. The use of photoplethysmograph (PPG) sensors in smartphones and smartwatches as AF screening tools is also growing. The WATCH AF research demonstrated how smartwatches can diagnose AF using PPG data better than cardiologist interpretations. However, in suspected AF situations, ECG confirmation is still required.

Additionally, the analysis of individual genomes and electronic health records (EHRs) for health insights has been done using ML frameworks. Offering a personalized approach to healthcare, Li et al. used high-coverage whole-genome sequencing (WGS) and hierarchical estimate from agnostic learning (HEAL) to find patterns and mutations linked to abdominal aortic aneurysms (AAA). This cutting-edge method is an excellent example of how ML and genomics might be used to identify and prevent diseases.

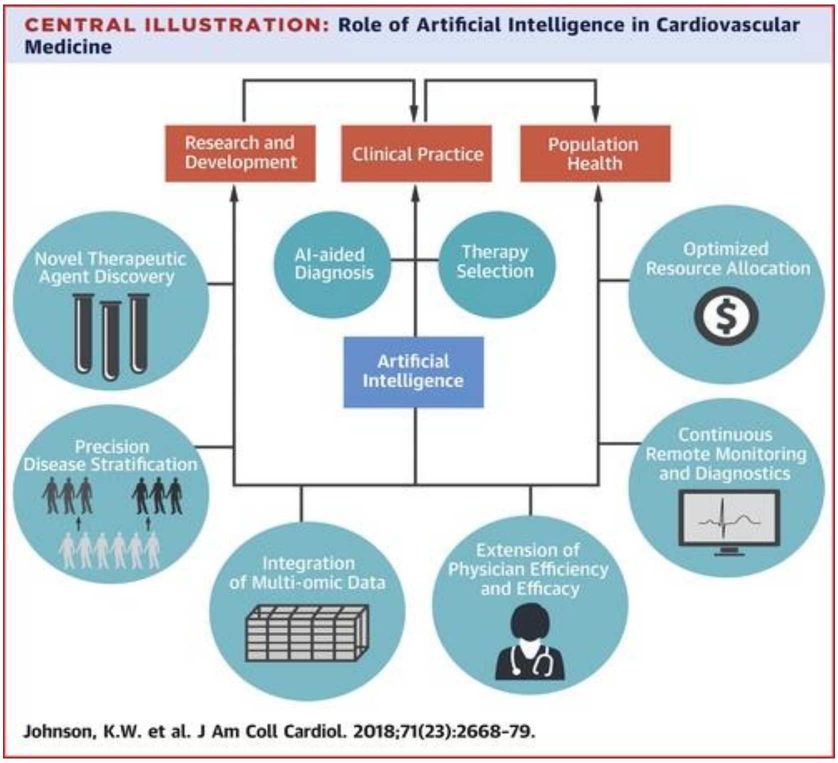

Figure 3: Role of AI/ML in cardiology.

(**Source**: Journal of the American College of cardiology.)

5. ROLE OF AI IN SURGERY

Wireless sensor networks (WSNs) are essential in healthcare because they provide real-time monitoring and feedback. They are made up of dispersed sensors that gather information about the environment, such as temperature, sound, and humidity, and send it to a central hub. WSNs are used in smart environments for a variety of purposes, including industrial automation and video monitoring. Artificial intelligence (AI) is a critical component of surgery, helping with illness detection, preoperative planning, intraoperative assistance, training, and robots. Data gathering for AI training, however, poses ethical questions concerning patient privacy. With potential uses in spectrum management, security, underwater acoustic sensors, and cognitive sensing, the need for AI-enabled WSNs is expected to increase in the future. In the end, AI-driven surgical learning has the potential to improve patient care by raising surgical training's efficacy and efficiency while taking ethical issues into account.

6. ROLE OF AI IN DIABETES MELLITUS AND CANCER MANAGEMENT

Chronic diabetes is characterised by high blood sugar levels brought on by inadequate or inefficient insulin usage. Machine learning and artificial intelligence (AI) are useful technologies for managing diabetes. They can help with accurate diabetic retinopathy identification, enhance glucose monitoring using cutting-edge tools, and even foretell the beginning of diabetes. The FDA-approved wearable gadget known as a continuous glucose monitor (CGM) allows for continuous monitoring of blood sugar levels, improving the treatment of diabetes. Contrarily, cancer is characterised by unchecked cell development and metastasizing to other bodily regions. AI has a big impact on cancer management, revolutionising research, diagnosis, and care. In addition to helping with cancer detection, AI also makes it easier to create personalised cancer treatments, finds novel therapeutic targets, speeds up the drug discovery process, and enhances cancer surveillance by examining patient and disease data.

Diabetes patients confront considerable difficulties, especially those who live in underprivileged areas. These obstacles include low levels of awareness, barriers to using healthcare systems, and a lack of access to drugs, all of which contribute to inadequate diabetes control and a higher risk of complications. Additionally, those with diabetes or hyperglycemia have greater mortality and recurrence rates following cancer diagnosis and treatment as well as a higher chance of acquiring a variety of malignancies.

The management of diabetes and cancer is changing as a result of wearable technologies and AI. Wearable technology, such as CGMs, allows for continuous monitoring in the management of diabetes, whilst AI provides early diagnosis and personalised cancer therapy. Although there are still difficulties, particularly in marginalised populations, wearable technology and AI integration have the potential to improve the results for patients with these disorders.

7. CHALLENGE AND FUTURE PROSPECTS

Medical fields including monitoring cardiac arrhythmias, managing diabetes, and assisting surgeries are all seeing substantial advancements thanks to artificial intelligence (AI) and machine learning (ML). They are essential for effectively processing intricate sensor data, assisting in data analysis, and enhancing decision-making. The performance of Internet of Medical Things (IOMT) devices is improved by AI/ML approaches' prowess in sifting through noisy or low-resolution data sources and extracting relevant insights.

Modern healthcare requires IOMT equipment, and their operation depends on connectivity. The seamless communication between patients and healthcare professionals is made possible by the ability of these gadgets to create both unidirectional and bidirectional connections. Bulk electronics are replaced with analogue front ends (AFEs) for signal conditioning, and microcontrollers are connected to AFEs via communication protocols such I2C, SPI, and UART. Wi-Fi and Bluetooth are the main communication channels for connecting IOMT devices with central hubs. While corporate Wi-Fi offers improved security and speed, Bluetooth is appropriate for short-range data transfer in environments like operating rooms and intensive care units. Smartphones have a major impact on the applications of IOMT devices because to their mobility. By allowing doctors and patients to communicate online through mobile devices, healthcare is made more accessible. However, the mobile healthcare ecosystem has to solve issues with security and privacy.

Integration of sophisticated AI/ML technology is key to IOMT's future. Affordability, multi-level functionality, high sensitivity, industrial-grade production, miniaturisation, and ultra-low power consumption are all expected to be features of AI-based IOMT devices. These innovations will be aided by advancements in nanotechnology and microelectronics, making it easier for people to receive high-quality healthcare.

8. CONCLUSIONS AND VIEWPOINT

In order to effectively use biosensing for illness management, this study emphasises current developments in AI-supported Internet of Medical Things (IOMT) devices. The creation of cutting-edge biomedical devices like e-skin, e-nose, and e-textiles that cooperate with AI and IOMT is made possible by the integration of nanotechnology, which is a primary area of attention. In crucial medical applications including heart monitoring, surgery, diabetes control, and cancer monitoring, these integrated devices are very important.

Medical fields including cardiac electrophysiology, surgery (like the Da Vinci surgical system), and personalised diabetes and cancer therapy have benefited greatly from AI. Because of the precision of the data, it offers the opportunity for early illness prediction and risk assessment. Among the several AI subcategories that are frequently used in the healthcare industry are machine learning, support vector machines (SVM), and neural networks (NN). Despite significant advancements, heterogeneity, connectivity, and sophisticated data management remain obstacles for AI. Even while AI cannot yet completely replace all medical jobs, it is constantly improving and proving its superiority. The study supports multidisciplinary research integrating IOMT, AI, and nano sensing to improve disease treatment and prevention in a personalised way.

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