Chapter 5

Book Chapter

Adaptation of IOT and AI technologies in Detecting Viral Infections and Cardiovascular Diseases

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Abstract

The integration of Internet of Things (IoT) and Artificial Intelligence (AI) technologies in healthcare has ushered in a new era of disease detection and management, significantly impacting the way viral and cardiovascular diseases are addressed. IoT devices, such as wearable sensors and environmental monitors, collect vast amounts of real-time data, which AI algorithms then analyze to detect early signs of infections or abnormalities. This synergy

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between IoT and AI has proven particularly effective in the early detection and monitoring of diseases like SARS-CoV-2, HIV, influenza, and various cardiovascular conditions. By leveraging AI's predictive analytics and machine learning models, healthcare providers can detect the impact of disease route, predict outbreaks, and mark treatment strategies with unprecedented accuracy. Despite the challenges of data privacy and integration into existing healthcare infrastructures, the advancements in IoT and AI have led to significant improvements in patient outcomes. These technologies are poised to play an increasingly central role in global health strategies, offering enhanced diagnostic capabilities, real-time monitoring, and personalized care solutions that can reduce the burden of disease and improve quality of life.

Keywords: Internet of Things (IoT). Artificial Intelligence (AI). SARS-CoV-2. Machine Learning Models.

1 Introduction

The incorporation of (IoT) and (AI) in healthcare endeavor to assess the path for the detection, monitoring, and treatment of viral diseases. IoT devices, such as wearable sensors and environmental monitors, collect data from patients and their surroundings to identify patterns indicative of viral infections using AI algorithms. The combined use of IoT and AI provides a powerful tool set for early detection and personalized treatment of viral diseases, which is critical in managing outbreaks and improving patient outcomes (Wu et al., 2020). The convergence of IoT and AI technologies has led to significant advancements in the healthcare industry, transforming how diseases are detected, monitored, and managed. IoT refers to the network of interconnected devices that collect and exchange data in real-time, while AI involves the practice of algorithms and machine learning models to elucidate the data and derive actionable insights. The integration of these technologies has proven particularly beneficial in the context of disease detection, where timely intervention is critical. In the realm of viral diseases, such as SARS-CoV-2, HIV, and influenza, wearable sensors and environmental monitors play a effective role in collecting real-time data on vital signs, environmental factors, and patient behaviors. AI algorithms then process this data to identify patterns that indicate the presence of a viral infection, enabling early detection and personalized treatment plans. For instance, during the COVID-19 pandemic, AI-powered diagnostic imaging and predictive analytics were instrumental in managing the surge of cases by providing rapid and accurate diagnoses, predicting outbreak trends, and optimizing resource allocation (Christakis & Fowler, 2010).

Cardiac diseases are among the significant health challenges in the world, given their morbidity and mortality rates, caused by a wide range of conditions that affect the heart. Recent advancement in technologies opened ways for new approaches in detection and monitoring of these diseases, especially in the context of IoT and AI integration. Literature

Editors: Shilpa Sivashankar, S.Pandikumar, Pallavi M O
DOI:10.48001/ 978-81-966500-0-1-5 | ISBN: 978-81-966500-0-1

indicates that most of the IoT-based systems developed for real-time monitoring and prediction of heart conditions have been very effective (Ko et al., 2017) In this regard, it has been found that systems utilizing gradient boosting and deep convolutional neural networks machine learning algorithms were quite accurate in diagnosing heart diseases using data obtained from wearable sensors and cloud-based platforms.

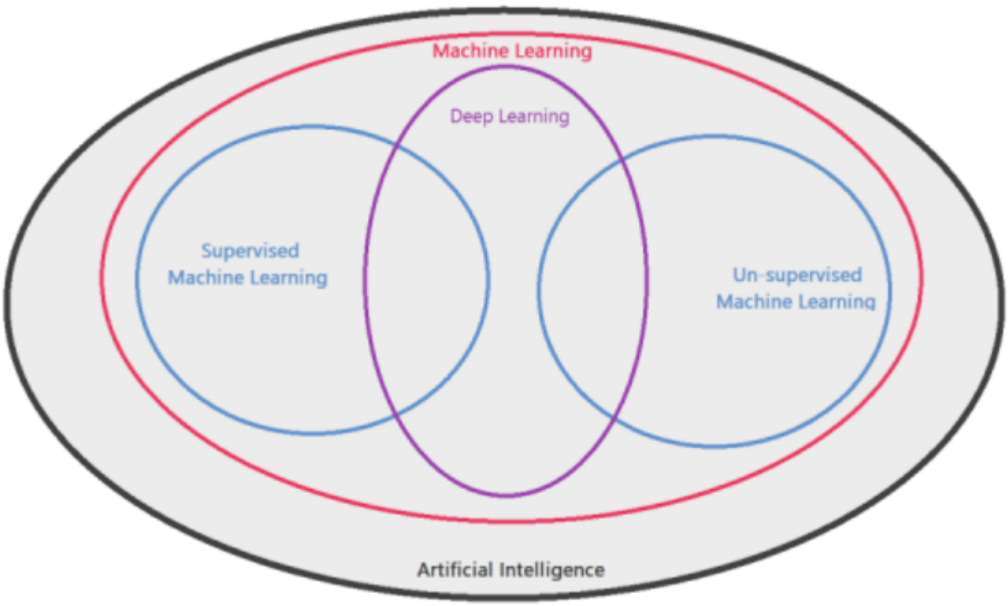

Figure 1. Vern Diagram on AI and Machine learning

Smart wearables integrated with deep learning technologies for tracking vital signs, monitoring continuously, can enable the early detection of problems in cardiovascular system (see figure 1). Research also strongly supports the integration of various data sources, such as heart sounds and e-health clinical records, to allow richer analytics aimed at making predictions of cardiac events and developing strategies for interventions. AI-driven frameworks, which include advanced deep learning using Bi-LSTM, seem very promising in refining predictive capabilities and management for cardiovascular health. The technological advances offer an integrated approach toward management of cardiovascular diseases, effectively enhancing the potential for early diagnosis and effective treatment of disease (Hinton, 2018).

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2 SARS-CoV-2 Detection

SARS-CoV-2, the virus responsible for COVID-19, primarily affects the respiratory system and has led to a global pandemic (Cascella202). The rapid spread and severe health impacts of the virus necessitated the development of advanced detection methods that could operate in real-time and at scale.

Mechanism of IoT Tools in SARS-CoV-2 Detection:

- Wearable Sensors for Vital Sign Monitoring: Wearable devices like smartwatches and fitness trackers are integrates with sensors to observe the temperature, heart rate, and oxygen saturation instantaneously (see figure 2). These physiological parameters are crucial indicators of SARS-CoV-2 infection. When a patient's deviate from normal physiological conditions, the IoT device transmits this data to healthcare benefactors, aiding early recognition and intervention. Several studies stating that, the wearable sensors can perceive changes in oxygen saturation levels up to 48 hours before clinical symptoms, helps to timely testing and isolation of the patients.

Figure 2. Wearable Health Monitoring Device

- Environmental Monitoring Sensors: Environmental IoT sensors are deployed in public spaces, such as hospitals and airports, to detect airborne SARS-CoV-2 particles (see figure 3). These sensors monitor air quality and detect viral RNA using advanced biosensors. The data collected is transmitted to cloud-based systems, where AI algorithms analyze the concentration and distribution of the virus in the environment. This real-time monitoring helps in identifying potential hotspots and implementing targeted

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disinfection protocols (Krishnan, Gupta, & Choudhury, 2018).

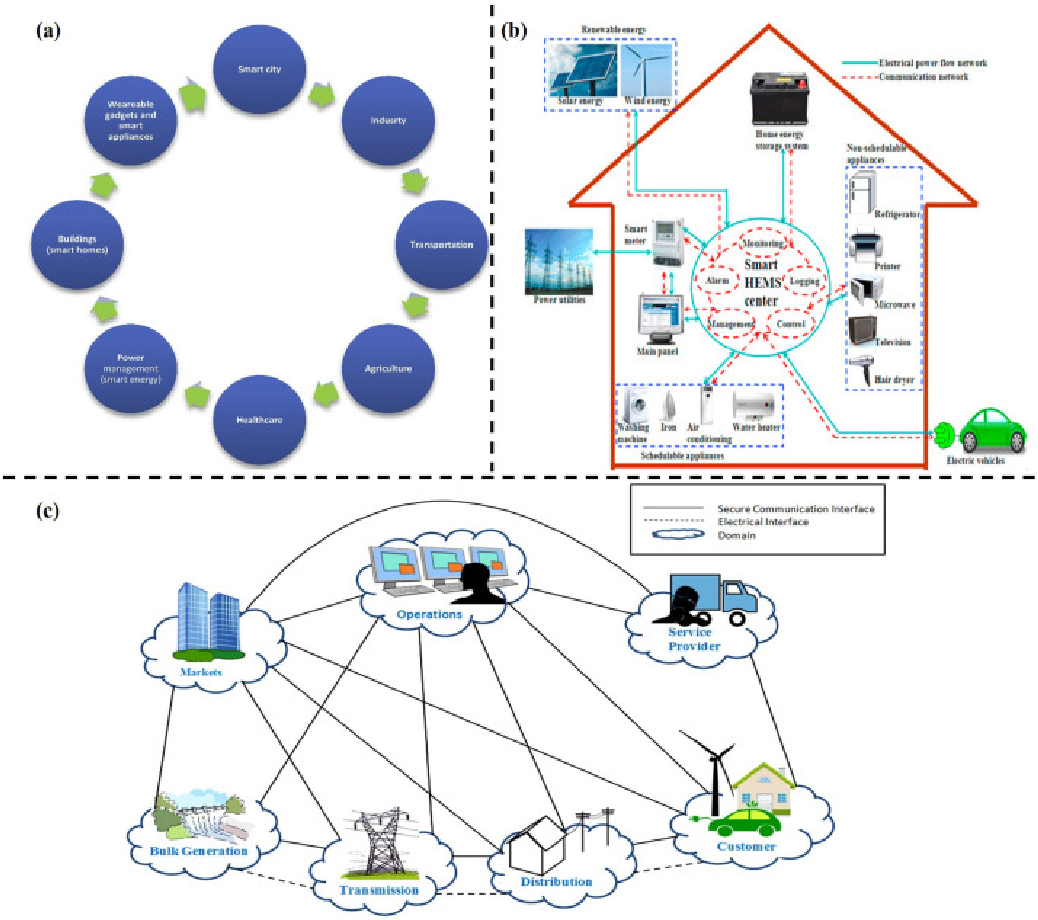

Figure 3. IoT Biosensor

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The mechanism of AI Tools in SARS-CoV-2 Detection :

- AI-Powered Diagnostic Imaging: The AI assisted imagining process is the most significant tool to identify the infection pattern of various viral diseases by collecting the large datasets of chest X-rays and CT scans using deep learning models (see figure 4). These algorithms can delineate anomalies in lung tissues, such as ground-glass opacities and bilateral infiltrates, which are characteristic of SARS-CoV-2 infection. The AI model processes the image data in seconds, providing a diagnosis with high accuracy. This rapid and accurate detection is crucial in managing the influx of patients during the pandemic (Fusco et al., 2021) .

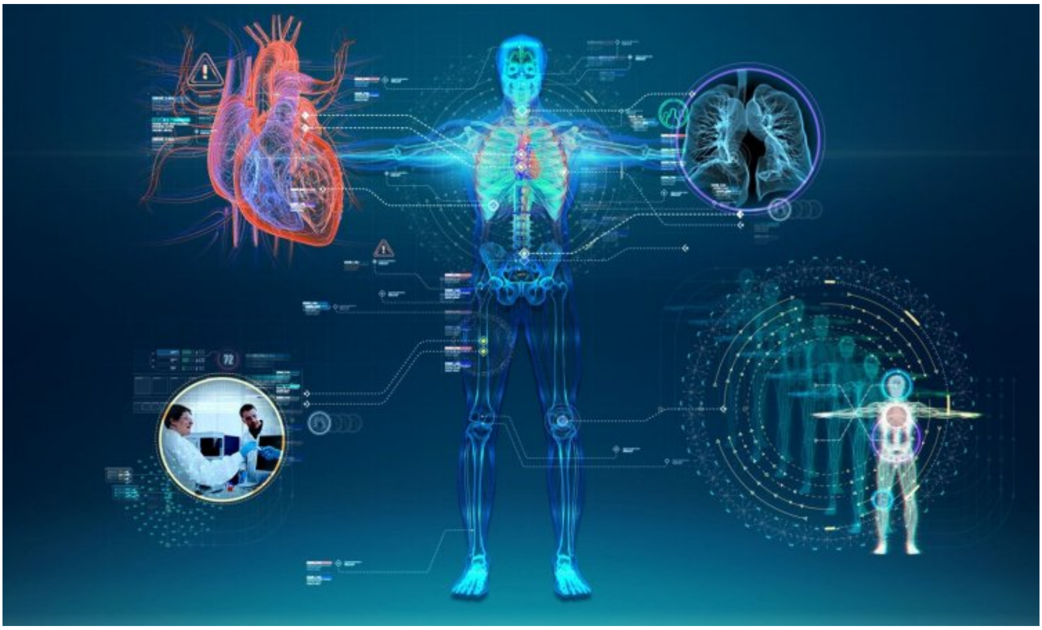

Figure 4. AI in Medical Imaging

- Predictive Analytics and Modeling: AI-based predictive models are developed to conjecture the spread of SARS-CoV-2. These models utilize the data from IoT devices, such as mobile phones and wearable sensors, to analyze mobility patterns, population density, and social interactions (see figure 5). By simulating different scenarios, the models can predict the impact of public health interventions, such as lockdowns and social distancing measures. These prophecies are vital for policymakers to make decisions and allocate resources effectively.

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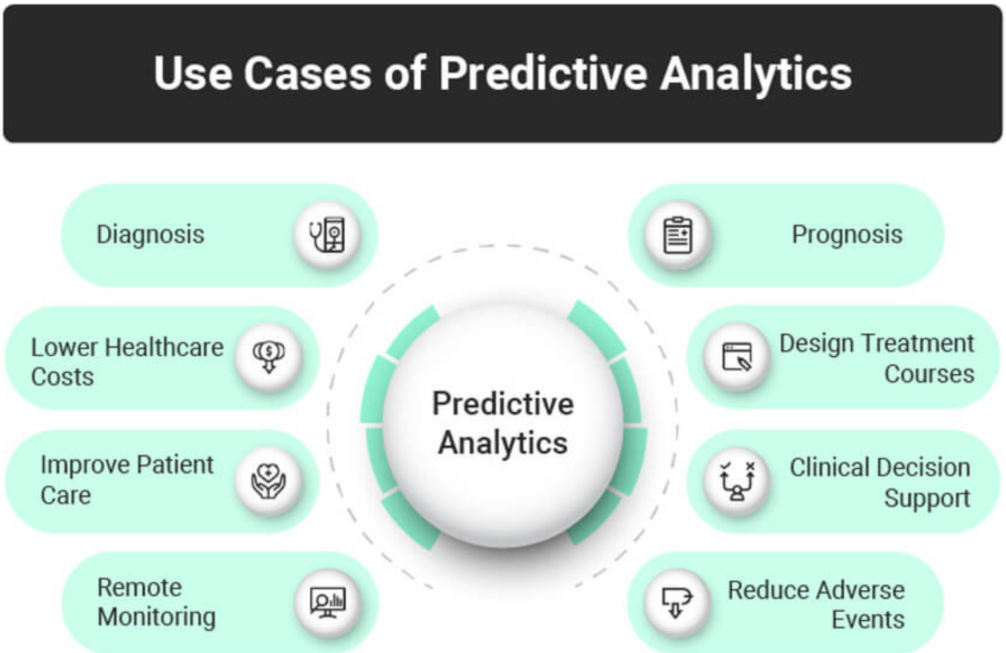

Figure 5. Predictive Analytics

2.1 Case Studies and Applications

Real-time Monitoring and Outbreak Detection: In a study conducted in Wuhan, China, IoT-enabled biosensors were used in combination with AI algorithms to monitor the spread of SARS-CoV-2 in hospitals. The system detected an outbreak in a hospital wing within hours of the first positive case, allowing for immediate isolation and disinfection. This rapid response significantly reduced the number of secondary infections.

3 HIV Detection

HIV is a retrovirus that targets the immune system, specifically CD4+ T cells, leading to progressive immunodeficiency and, if untreated, the development of AIDS. Early detection and continuous monitoring are critical in managing HIV and preventing its progression (Annolino, 2022).

Mechanism of IoT Tools in HIV Detection :

- Implantable Biosensors for Viral Load Monitoring: Implantable IoT biosensors are de-

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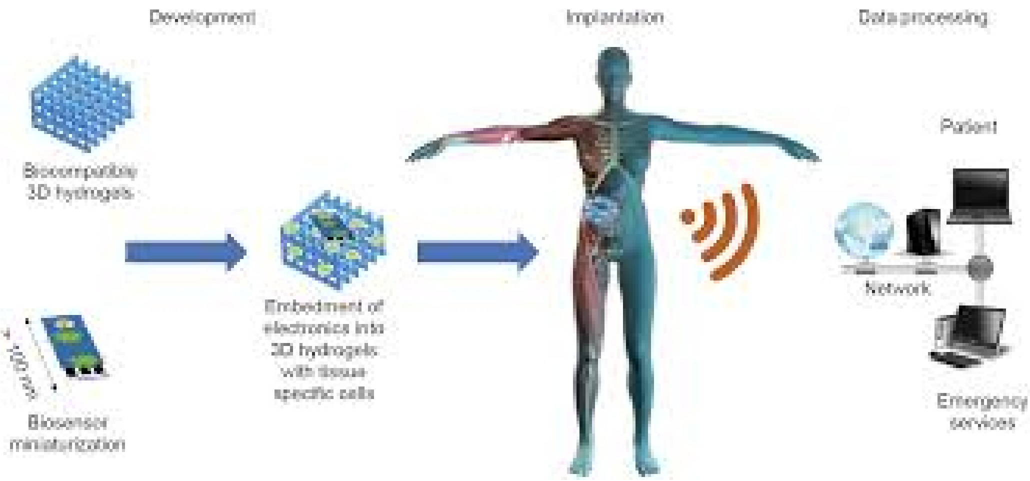

Figure 6. Implantable Biosensor

signed to monitor HIV viral load in real-time. These sensors detect specific biomarkers, such as HIV RNA and CD4+ T cell counts, in the bloodstream (see figure 6). The data is wirelessly transmitted to external devices, where it is analyzed and sent to healthcare providers. This incessant monitoring leads for immediate adjustments to antiretroviral therapy (ART) which improves patient outcomes and tumbling the menace of drug resistance (Ani et al., 2017).

- Smart Medication Adherence Systems: IoT-enabled smart pillboxes and medication adherence systems monitor the medicinal history of the patients about their prescribed ART (see figure 7). These devices are connected to mobile apps that remind patients to take their medication and alert healthcare providers if doses are missed. Ensuring adherence to ART is crucial in maintaining low viral loads and preventing the development of resistance.

Mechanism of AI Tools in HIV Detection :

- Deep Learning (DL) for Genomic Analysis: The DL models are used to analyze the genomic sequences of HIV infected patients (see figure 8). These models can identify mutations in the gene sequences of virus that may lead to drug resistance. In addition, this analysis helps to predict the occurrence of mutational genome precisely. Eventually, the AI can assist in developing personalized treatment plans that are tailored to the patient's specific viral strain, improving the effectiveness of ART (Andarevi & Iskandar, 2022).

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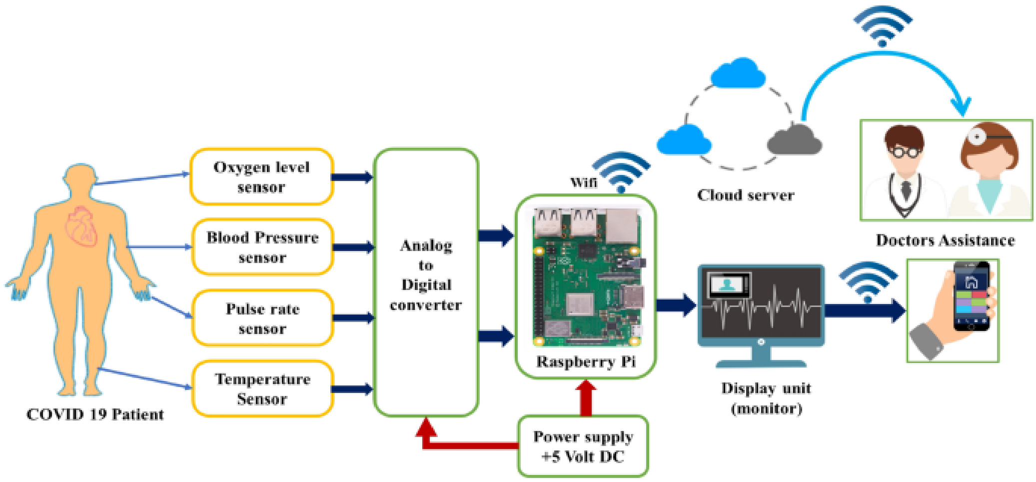

Figure 7. Smart Health Monitoring System

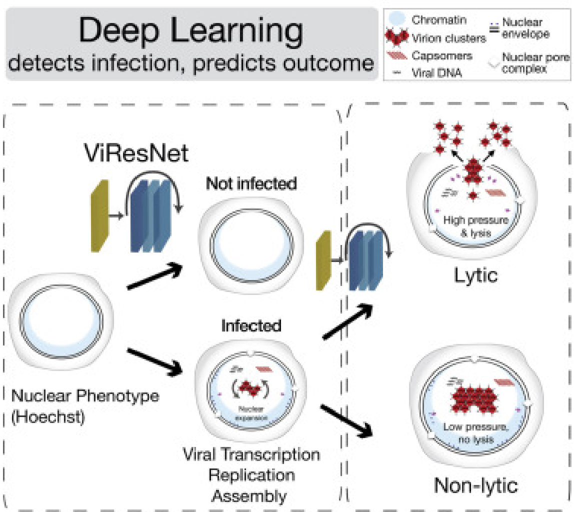

Figure 8. Deep Learning for Viral Load Prediction

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- AI-driven Personalized Treatment Plans: In this process, the treatment plans for HIV patients are sequestered by examining the sequence of genome, electronic health records (EHRs) by synchronizing AI algorithms in IoT devices (see figure 9). These plans take into account the patient's health status, viral load, and potential drug resistance, optimizing ART regimens and improving patient outcomes (Guo et al., 2023).

Figure 9. Personalized Treatment Plans

3.1 Case Studies and Applications

Impact on Treatment Adherence: A study conducted in sub-Saharan Africa demonstrated that the use of IoT-enabled adherence monitoring systems, combined with AI-driven treatment optimization, significantly improved ART adherence rates. Patients using the system showed a 30% increase in adherence compared to those who did not, leading to better viral suppression and reduced transmission rates.

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4 Influenza Detection

Influenza is a contagious respiratory illness caused by influenza viruses. It can lead to severe illness and even death, particularly in vulnerable populations. The virus mutates rapidly, making early detection and monitoring essential for controlling outbreaks.

Mechanism of IoT Tools in Influenza Detection :

- Connected Thermometers for Fever Detection: IoT-enabled thermometers are widely used to measure body temperature in real-time (see figure 10). Fever is a common symptom of influenza, and these devices can track temperature trends and alert healthcare providers to potential infections. These systems can predict influenza outbreaks by analyzing temperature data across large populations by integrated with AI (Alshamrani, 2022).

Figure 10. Connected Thermometer

- Environmental Sensors for Air Quality Monitoring: IoT devices equipped with biosen-

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sors are deployed in public spaces to detect influenza virus particles in the air (see figure 11). These devices quantify air quality and can identify the presence of the virus by detecting specific viral RNA sequences. The data has been forwarded to cloud servers the likelihood of an outbreak using AI algorithms (Piccialli et al., 2021).

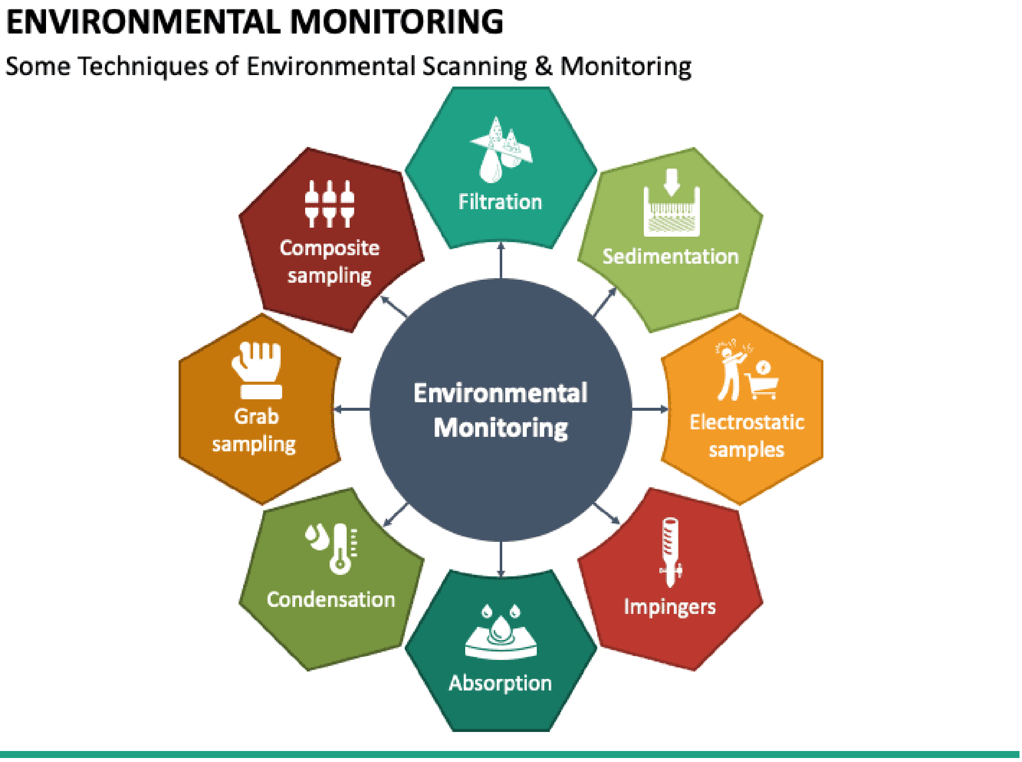

Figure 11. Environmental Monitoring System

Mechanism of AI Tools in Influenza Detection:

- AI-based Predictive Analytics: AI tools use predictive analytics to forecast influenza outbreaks. By analyzing data from IoT devices, social media, and historical health records, AI models can predict the timing and severity of flu seasons. These predictions help public health authorities prepare for and mitigate the impact of outbreaks, such as by increasing vaccine production or implementing public health campaigns.
- Symptom Recognition via AI: AI algorithms are also employed to recognize influenza symptoms from audio and visual inputs (see figure 12). For example, AI models can analyze cough sounds to differentiate between influenza and other respiratory illnesses.

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This capability is especially useful in telemedicine, where physical examination is not possible .

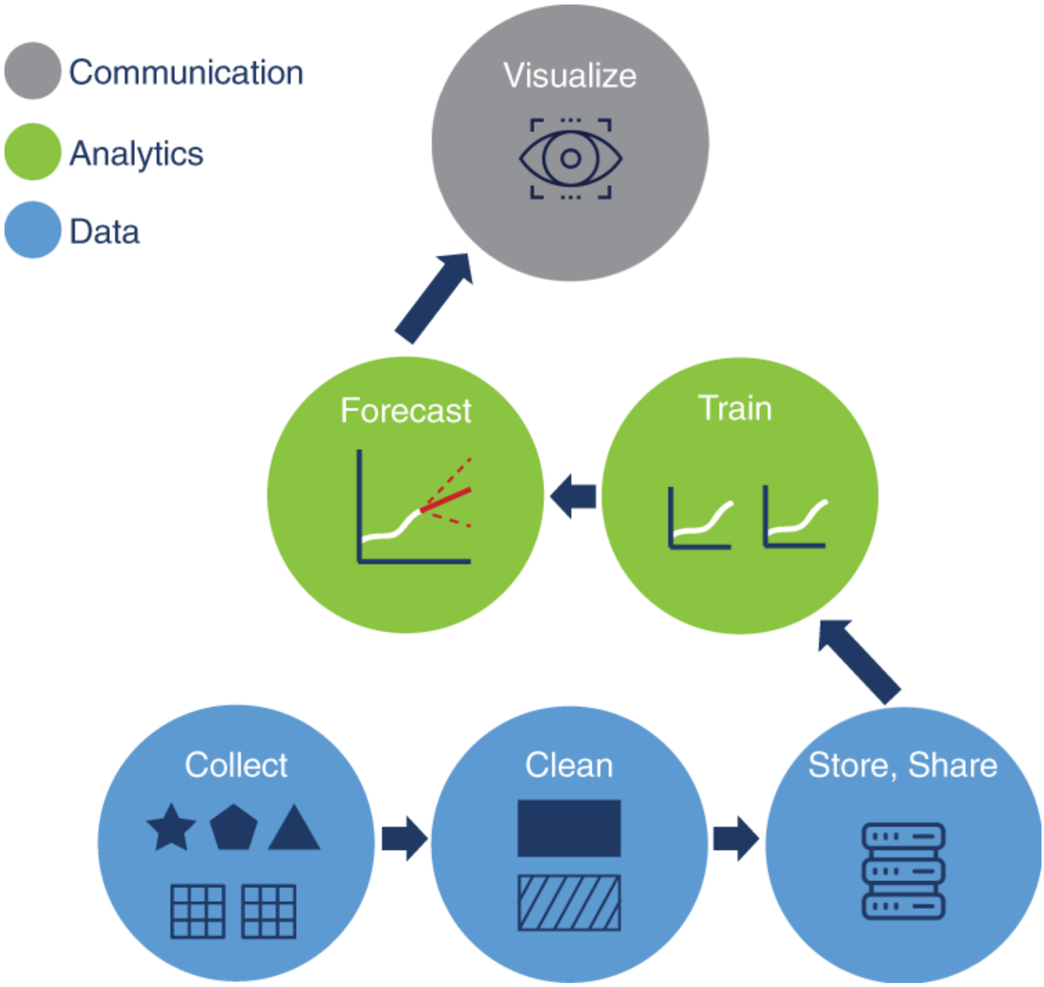

Figure 12. Outbreak Forecasting

5 Comparative Analysis of IoT and AI Adaptations

- Strengths and Weaknesses
  The strengths of IoT and AI technologies in viral disease detection include their ability to collect and process large volumes of data in real-time, provide personalized treatment

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plans, and predict outbreaks. However, safeguarding of data, handling of enormous amount of data generated and integrating the technologies into existing healthcare systems is the biggest challenge in AI applications in health attention system.

- Cross-Virus Applications
  For instance, AI algorithms used for SARS-CoV-2 detection can be retrained for other types of virus like influenza, while IoT devices can be reconfigured to monitor different biomarkers relevant to various viral infections .
- Future Directions in Viral Disease Detection
  Future developments in IoT and AI are likely to focus on improving the accuracy and scalability of these technologies. Advances in sensor technology, machine learning algorithms, and data integration will enable more precise and timely detection of viral infections, ultimately enhancing public health responses and patient outcomes.

6 Technological Evolution Of Iot & AI In Cardiac Disease Detection

The development of IoT and AI technologies in healthcare, particularly for cardiovascular disease management, has evolved significantly over the past two decades. From the early 2000s to 2010, these technologies were in their infancy. IoT devices were limited to basic monitoring of vital signs, without the capability for real-time analytics or advanced integration. During this period, AI was still dominated by traditional statistical methods and basic machine learning models. Research efforts primarily focused on medical imaging and simple predictive models, with little impact on cardiovascular disease management. As a result, the influence of these technologies on clinical practice and patient outcomes remained minimal, limited to pilot studies and experimental projects. The 2010 to 2020 period marked substantial progress, with the introduction of more advanced IoT devices capable of continuous real-time data transfer. AI algorithms also evolved, with techniques like support vector machines, random forests, and early neural networks facilitating more sophisticated data analysis and risk prediction. The integration of AI with EHRs and imaging technologies improved diagnostic accuracy and enabled more personalized treatment plans. These advancements transformed cardiovascular care, significantly enhancing early detection, risk prediction, and personalized care, which resulted in better patient outcomes and more efficient healthcare delivery.

DOI:10.48001/ 978-81-966500-0-1-5 | ISBN: 978-81-966500-0-1

From 2020 to the present, IoT and AI technologies have reached a mature stage, with the development of advanced deep learning models such as convolutional neural networks (CNNs) and long short-term memory (LSTM) networks. These models can identify complex patterns in cardiovascular data with high precision. Additionally, sophisticated wearables now offer continuous real-time monitoring of key metrics like heart rate, blood pressure, and ECG signals, often integrated with cloud-based platforms for comprehensive analysis (see figure 13). This seamless integration allows for the aggregation of data from multiple sources, enabling timely predictions and interventions. As these technologies continue to advance, they are driving transformative changes in cardiovascular disease management by improving predictive accuracy, enhancing remote monitoring, and facilitating more personalized care.

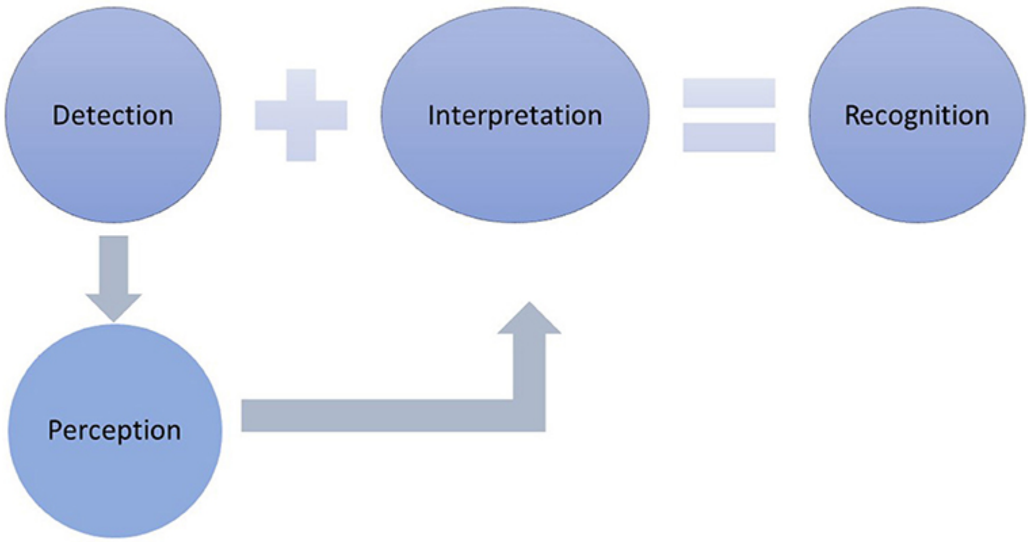

Figure 13. Symptom Recognition

6.1 Instruments And Protocols

Smartwatches, fitness trackers, wearable sensors, and digital stethoscopes are integral components of modern healthcare, especially in cardiovascular monitoring. These devices enable continuous data collection by tracking key health metrics such as heart rate, ECG signals, blood pressure, oxygen saturation, and physical activity levels. Smartwatches and fitness trackers provide real-time monitoring, while wearable sensors give a more com-

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prehensive view of cardiovascular health by measuring heart rate variability and oxygen levels. Digital stethoscopes enhance diagnostic capabilities by capturing heart sounds and analyzing them through machine learning algorithms.The protocol for utilizing these IoT devices begins with data collection, where smartwatches, ECG monitors, and sensors continuously log and timestamp health information to create a consistent health record. This data is then securely transmitted to cloud servers through encrypted communication protocols, ensuring privacy and enabling the aggregation of data from multiple devices. Data processing follows, involving the cleaning of raw data to remove noise and artifacts, normalizing it, and extracting relevant features for analysis. Next, model training occurs on cloud servers using advanced deep learning models like recurrent neural networks (RNNs) and long short-term memory (LSTM) networks (see figure 15). These models are trained on historical data, using optimization techniques like backpropagation and gradient descent, with regularization to prevent overfitting (see figure 14). The models are continuously evaluated against various datasets to fine-tune hyperparameters for better performance.

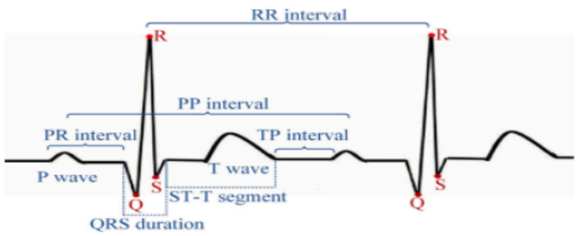

Figure 14. The AI–ECG to detect HCM

In real-time analysis, the system continuously ingests new data from IoT devices, enabling the detection of anomalies that may indicate cardiovascular risks. If risk metrics exceed predefined thresholds, real-time alerts are triggered and sent via notifications, SMS, or email, ensuring timely intervention. All health data is securely stored in the cloud for longitudinal analysis, helping track health trends over time while ensuring compliance with privacy regulations like HIPAA and GDPR. Lastly, interoperability ensures seamless sharing of patient data and predictive insights with healthcare providers through integration with EHRs and other health systems (see figure 17). This enables personalized treatment plans based on continuous health data, improving clinical decision-making and patient outcomes. Regular updates and retraining of the models further enhance predictive capabilities, making the system more effective in long-term healthcare management.

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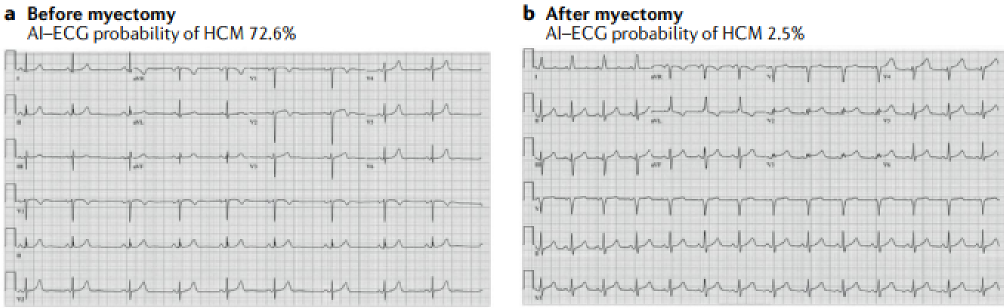

Figure 15. Waveform and interval characteristics of two complete cycles of ECG

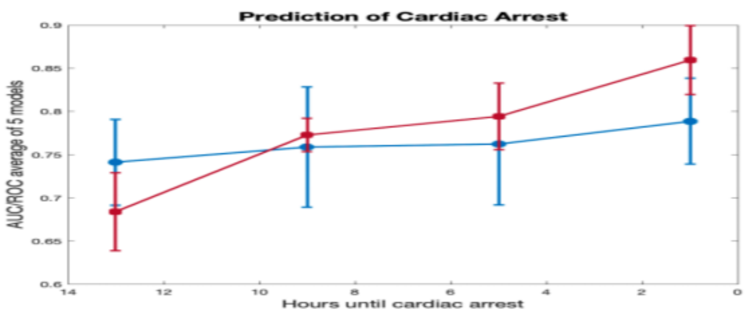

Figure 16. Prediction of time until cardiac arrest through heart vital monitoring

6.2 Statistical Analysis

The evolution of predictive accuracy, early detection, and patient monitoring in healthcare, especially for cardiovascular conditions, has shown remarkable progress over the years. In the early 2000s, predictive models achieved accuracy rates of around 60-70%, limited by smaller datasets and less advanced algorithms. From 2010 to 2020, the integration of improved algorithms and larger, more diverse datasets boosted accuracy to 80-85%, with the adoption of machine learning techniques and Electronic Health Records (EHRs) enhancing outcomes. Currently, models based on deep learning methods exhibit accuracy rates between 85% and 95%, offering robust diagnostic capabilities and reliable risk assessments to support clinical decision-making.

In terms of early detection, the early 2000s relied primarily on symptom presentation, which often delayed intervention and led to poorer outcomes. From 2010 to 2020, advance-

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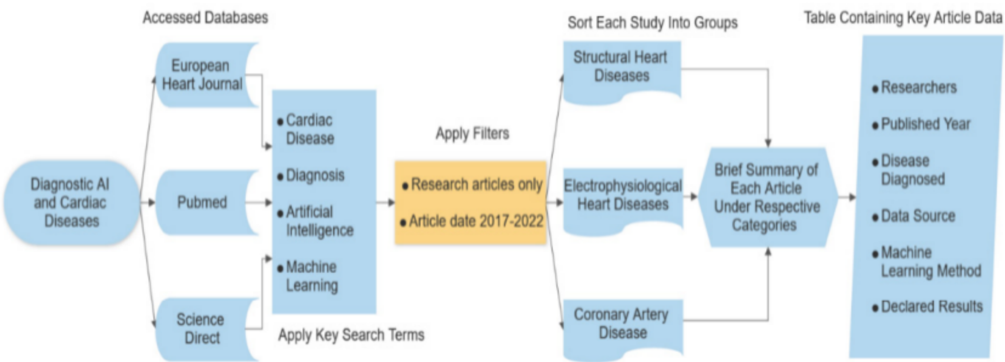

Figure 17. Flow chart for method design

ments in AI-driven analytics and monitoring systems reduced detection time by 30-40%, improving the identification of cardiovascular abnormalities. Presently, cutting-edge technologies have further reduced detection time by up to 50%, ensuring faster interventions and enhancing disease management through continuous monitoring and real-time alerts. Patient monitoring has also advanced significantly over the years. In the early 2000s, manual monitoring methods were common, with long gaps between data collection, limiting effective analysis. Between 2010 and 2020, wearable devices and remote monitoring systems enhanced patient tracking, reducing emergency hospital visits by 20-30%. Today, sophisticated wearables offer continuous monitoring, decreasing emergency visits by 30-40% and improving preventive care through real-time alerts and predictive analytics. These advancements enable timely interventions and contribute to better patient outcomes and overall healthcare management.

6.3 Bridging of AI and IOT tools on cardiovascular disease

AI and IoT technologies represent the paradigm shift in the management of cardiovascular diseases. Modern devices on the IoT include smartwatches and wearable sensors that collect a significant amount of physiological data relating to heart rate, blood pressure, ECG readings, and activity levels. The data collected in real-time by these devices is then transferred to cloud-based platforms to be processed and analysed by AI algorithms. AI technologies, and more importantly machine learning models, really shine when asked to find patterns and outliers in large data sets. Applied to data gathered from IoT devices, AI picks up slight changes that could indicate early cardiovascular problems. AI can spot

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irregular heartbeats, unusual changes in blood pressure, or deviations from a patient's baseline metrics in order to pinpoint arrhythmias, heart attacks, or chronic heart failure. Diagnostic accuracy in AI-IoT-integrated outcome and continuous health monitoring with real-time feedback will therefore be able to let this proactive approach open early intervention possibilities, hence potentially averting emergency situations that would have led to hospital admission. AI-driven analytics will permit individualization of treatment plans with predictions at the level of the individual of health risks, together with suggestions of tailored lifestyle modifications or medical interventions. Cloud-based AI systems allow seamless sharing of data among various healthcare providers with the view of availing an exact picture of health to the concerned parties. This will enhance coordination and continuity of care and hence assure an informed decision-making process. AI and IoT applications for cardiovascular health reach as far as engaging patients through real-time alerts and advisories that provide them with the power and charge to actively take better care of their health (Khan et al., 2022).

7 Conclusion

The integration of IoT and AI technologies represents a transformative advancement in healthcare, particularly in the detection and management of viral diseases. These tools facilitate early detection, personalized treatment, and real-time monitoring, helping to control infections and prevent their spread. As these technologies evolve, their role in improving public health and patient care will continue to grow. The synergy between advanced AI algorithms and IoT devices enhances diagnostic accuracy and outbreak management, especially through wearable technologies and biosensors that enable continuous health monitoring. This proactive approach ensures faster interventions and better containment of diseases, reducing the strain on healthcare systems. Future research will aim to refine these technologies for greater sensitivity and specificity, develop robust algorithms for diverse data, and integrate AI-driven decision support systems into public health strategies. In cardiovascular disease management, these advancements have already revolutionized patient care, offering more precise detection, prediction, and treatment. Continued collaboration among technology developers, healthcare professionals, and policymakers will be crucial to fully harness the potential of IoT and AI in improving global health security and ensuring better health outcomes.

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