Investigation of Deep Learning and Machine Classifications for IOT-Enabled Medical Devices

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ABSTRACT

The Internet of Things (IoT) is revolutionizing academia and research, particularly in domains like healthcare. This technology integrates seamlessly with wearable devices, sensors, and cloud computing advancements, facilitating widespread adoption. IoT has facilitated the shift from traditional centralized healthcare systems to personalized healthcare systems (PHS). However, alongside its benefits, IoT presents challenges such as increased costs, data storage requirements, and device heterogeneity maintenance. This paper explores IoT's robust application in healthcare, incorporating machine learning and deep learning techniques. It outlines an IoT-enabled system framework, its advantages, and current applications, as well as discusses challenges. Furthermore, it surveys various studies demonstrating IoT's role in enhancing healthcare delivery by improving patient-professional relationships, predicting critical medical conditions, and optimizing resource management.

INTRODUCTION

Healthcare is indispensable in ensuring well-being, focusing on enhancing and maintaining health through timely disease diagnosis [1]. Technological advancements have revolutionized early detection, enabled proactive measures and improved patient outcomes. Technologies such as CT, PET, and MRI facilitate deep tissue diagnostics, pre-emptively identifying conditions like diabetes and heart disease before symptoms manifest [18]. However, escalating global populations and healthcare demands strain existing systems, necessitating solutions that uphold quality while serving all [19].

Recent attention has turned to IoT (Internet of Things), which integrates internet-connected devices to streamline healthcare delivery [20, 23]. IoT in healthcare empowers personalized monitoring and early disease detection remotely, optimizing intervention strategies [24]. This article explores remote healthcare systems that enhance accuracy and accessibility, pre-emptively mitigating critical conditions.

Moreover, machine learning and deep learning algorithms are pivotal in refining diagnostic precision across various medical domains, underscoring their efficacy [references needed]. This article consolidates insights from diverse researchers advancing IoT-based healthcare systems with machine learning and deep learning techniques.

The article's structure proceeds the motivation behind the research, a comprehensive background study encompassing healthcare frameworks, types, and limitations, extensive related work, comparative analyses, and concluding remarks.

Motivation

Global efforts are intensifying to combat prevalent diseases afflict large populations, yet gaps persist in timely disease detection and healthcare access [25-26]. IoT has emerged as a transformative force in healthcare, facilitating remote patient monitoring, electronic health records, and preventive care initiatives [27]. Its implementation promises streamlined hospital management, reduced errors, optimized medication administration, and enhanced medical outcomes.

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BACKGROUND STUDY

This section delves into IoT frameworks, types of IoT-based healthcare devices, research challenges, and the role of algorithms in optimizing IoT healthcare solutions.

IoT Healthcare Framework

IoT healthcare systems typically operate across three tiers:

- Tier 0: Sensors gather diverse physiological and geographical data.

- Tier 1: Data processing occurs to refine gathered information.

- Tier 2: Processed data is transmitted for monitoring, analysis, and storage, often in cloud-based databases [11].

This framework, outlined by Vermesan et al., underscores IoT's role in advancing healthcare delivery and management.

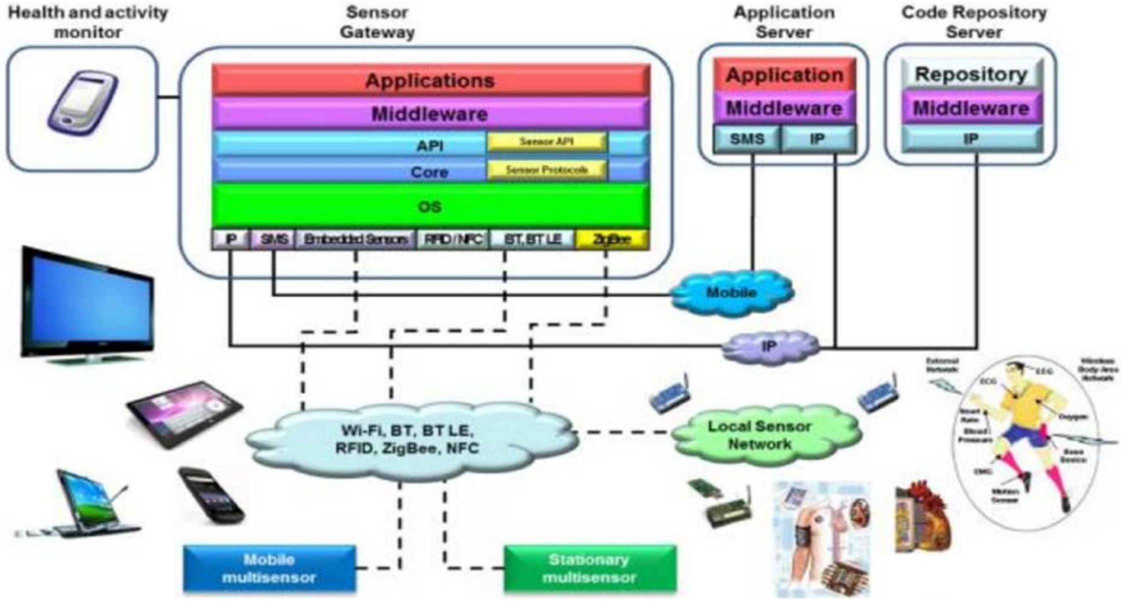

Fig 1. IoT based Smart Health Platform [11]

Types of IoT-Based Healthcare Devices

Various successful IoT-based healthcare devices exemplify the diverse applications in the field:

- ColdTrace System: Monitors vaccine refrigerator temperatures remotely using sensors, ensuring data collection on current temperatures. This system is pivotal in maintaining vaccine efficacy. Similar in concept is Stove Trace.

- System One: This system is designed to facilitate real-time data transmission to healthcare professionals, enhancing their connectivity and enabling better public health management, underscoring their integral role in the IoT-based healthcare system.

One notable example is Pfizer, which tracks the effectiveness of Parkinson's drugs by collecting real-time data. This enables timely dosage adjustments, a significant advancement in patient care.

These examples not only demonstrate the robust capabilities of IoT-based healthcare systems but also underscore their transformative potential, significantly impacting medical practices and improving patient outcomes.

Prediction-Making Approach

Studies employing machine learning and deep learning architectures follow a structured prediction-making framework. This Approach typically involves four fundamental steps:

1. Data Collection: Gathering relevant medical data for analysis.

2. Feature Extraction: Identifying and extracting pertinent features from the collected data.

3. Algorithm Application: Utilizing machine learning or deep learning algorithms, where extracted features serve as inputs.

4. Prediction Comparison: This crucial step involves comparing algorithm-generated predictions with actual values, a process that ensures the precision and efficiency of our prediction-making Approach.

Figure 2 illustrates this prediction-making framework in diagnostic studies.

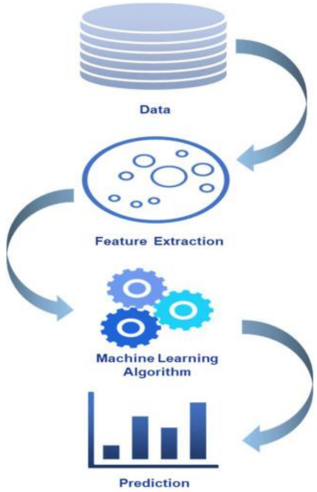

Fig 2. Prediction Making

REPORTED WORK

This section delves into various researchers' contributions in leveraging IoT-based solutions for healthcare, employing diverse machine learning and deep learning algorithms to address specific medical challenges.

Shirin et al. [3] focused on detecting Urinary Tract Infections (UTI) in dementia patients using IoT-enabled healthcare systems. They utilized non-negative matrix factorization (NMF) for latent feature extraction and isolation forest to identify changes in daily activity patterns. Their unsupervised learning approach outperformed the baseline model (One-class SVM), achieving a validation rate of 15% compared to 4%.

Masood et al. [4] developed an IoT-enabled Computer-Aided Diagnosis (CAD) system for detecting Pulmonary Cancer using wearable sensors and CT scan images. Their deep learning model, DFCNet, based on a fully convolutional neural network, achieved significant results in identifying lung nodules across all stages of cancer, with a median dice score of 91.34%.

Das et al. [5] proposed a cloud-based teleophthalmology architecture for diagnosing Age-Related Macular Degeneration (AMD) via IoT. They utilized CNN (AMD-ResNet) for analyzing retinal fundus images, achieving high specificity (98.32%) and sensitivity (94.97%). Their LSTM-based model also predicted AMD progression with an accuracy of 97.49 ± 0.4%.

Memon et al. [6] employed IoT in detecting Breast Cancer, using support vector machines (SVM) with recursive feature selection. Their model achieved remarkable accuracy (99%), specificity (99%), sensitivity (98%), and Mathew's correlation, demonstrating its robust performance in diagnosing breast cancer.

Khamparia et al. [7] developed a deep learning framework driven by IoT to detect Cervical Cancer from Automated Pap smear images. Combining CNN (ResNet50) with random forest achieved an accuracy of 97.89%, highlighting its effectiveness in early cancer detection.

Chatrati et al. [8] implemented a smart home health monitoring system for detecting Type 2 Diabetes and Hypertension using glucose and blood pressure readings. Their SVM-based classification approach, integrated with a user-friendly GUI, attained an accuracy of 75% in predicting diabetes.

Alfian et al. [9] utilized BLE-based sensors to monitor people with diabetes, employing Multilayer Perceptron and LSTM for early diagnosis and glucose level prediction. They achieved an accuracy of 77.083% using the PIMA dataset and demonstrated effective forecasting capabilities with LSTM.

Isravel et al. [10] developed IoT-based diagnostic models for heart disease, employing preprocessing techniques and algorithms like K Nearest Neighbors (KNN), Decision Trees, and Naive Bayes. Their KNN model achieved 90% accuracy in predicting heart disease, utilizing sensors such as LM35 Temperature Sensor and ECG Sensor.

These studies underscore the transformative impact of IoT and advanced machine learning techniques in enhancing diagnostic accuracy, monitoring capabilities, and treatment outcomes across various critical healthcare domains.

COMPARATIVE ANALYSIS

This section displays the comparatives analysis of the reported work by different researchers in the Healthcare domain using IoT.

TABLE I. COMPARATIVE ANALYSIS

AUTHORS	DISEASE	DATASET	TECHNIQUE	RESULT
Claas et al. [2]	Parkinson's Disease	Gathered data of 20 patients	SVM with kernel	Accuracy:98%
Shirin et al. [3]	Dementia using UTI	Gathered with 53 participants	NMF and Isolation Forest	Validation:15%
Masood et al. [4]	Pulmonary cancer	CT scan images	CNN	Dice coefficient:91.34%
Das et al. [5]	AMD	Retinal fundus images	CNN(AMD-ResNet), LSTM	specificity:98.32%, sensitivity:94.97%, accuracy:97.49%
Memon et al. [6]	Breast Cancer	Wisconsin Diagnostic Breast Cancer	SVM, recursive feature selection	accuracy:99% specificity:99%, sensitivity:98% Matthew's correlation : 98%.
Khamparia et al.[7]	Cervical cancer	PapSmear Herlev dataset	CNN(ResNet50) and random forest	accuracy:97.89%

DISCUSSION

This section provides a comprehensive overview of the critical aspects of studying IoT-based healthcare systems.

The Internet of Things (IoT) has significantly transformed various industries, particularly healthcare, by integrating wearable devices [18], sensors, and cloud computing. This shift has enabled a transition from traditional facility-centric healthcare to personalized healthcare systems (PHS). However, alongside its transformative benefits, IoT in healthcare also faces several challenges and limitations, which are highlighted in this study.

According to Cisco, IoT-based healthcare initiatives often need help with issues such as incomplete or unsuccessful project implementations, as evidenced by a survey indicating only a 26% completion rate. Furthermore, these systems generate vast data, leading to storage challenges and increased operational costs. Security concerns also loom large, with IoT devices presenting vulnerabilities that can be exploited by malicious actors, necessitating robust security measures and regular device updates to safeguard patient information.

This review examines the applications of IoT in healthcare, mainly focusing on machine learning and deep learning techniques. It outlines the framework of IoT-enabled systems, their advantages, and their current applications across various healthcare domains. Despite challenges, IoT has facilitated stronger interactions between healthcare providers and patients, enabled early diagnosis of critical medical conditions, and optimized healthcare resource management.

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CONCLUSION

This study reveals that IoT-based healthcare systems offer substantial robustness and efficacy. When coupled with appropriate machine learning and deep learning techniques, these systems enhance the ease, accuracy, and remote accessibility of disease detection processes. Integrating IoT with machine learning represents a revolutionary advancement in the healthcare domain.

Throughout this article, we have explored the benefits and diverse types of IoT-based healthcare systems and the challenges encountered during their implementation. We have reviewed contributions from various researchers who have proposed innovative machine learning and deep learning models for disease detection. The reported works illustrate IoT's pervasive influence across medical disciplines, demonstrating significant achievements in addressing diseases such as cancer, dementia, Parkinson's, diabetes, hypertension, and more.

Continued refinement and redesign of machine learning models will further improve disease prediction accuracy and enhance overall healthcare outcomes.

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