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Article

A SMART HEALTHCARE MONITORING SYSTEM UTILISING MACHINE LEARNING AND INTELLIGENT IOT TECHNOLOGY

P. Swapna Shankar[1], Dr. Sunkara Ramesh Kumar[2], Dr. Bharati Kawade[3], Prasanna Palsodkar[4], Dr. Sunil Gagare[5], Mahendra Sanjay Dalvi[6]

[1]Assistant Professor, Department of Computer Science and Engineering – Cyber Security, Geethanjali College of Engineering, Cheeryal, Hyderabad – 501301, Telangana, India. Email: pswapnashankar@gmail.com
[2]Assistant Professor, Department of Computer Science and Engineering, Koneru Lakshmaiah Education Foundation, Green Fields, Vaddeswaram, Guntur – 522302, Andhra Pradesh, India. Email: cadramesh@kluniversity.in
ORCID: 0000-0002-1096-9582. Scopus ID: 56695011800. Web of Science ID: T-3002-2018
[3]Vishwakarma University, Pune, Maharashtra, India. Email: bharati.kawade27@gmail.com
[4]Department of Electronics Engineering, Yeshwantrao Chavan College of Engineering, Nagpur, Maharashtra, India. Email: palsodkar.prasanna@gmail.com
[5]Assistant Professor, Department of Electronics & Telecommunication Engineering, Amrutvahini College of Engineering, Sangamner, Affiliated to Savitribai Phule Pune University, Pune, Maharashtra, India. Email: sunilgagare@yahoo.co.in
[6]Sandip Institute of Technology and Research Centre, Nashik, Maharashtra, India. Email: dalvimahendra21@gmail.com
Corresponding Author: P. Swapna Shankar

Abstract: Smart healthcare monitoring systems integrate Internet of Things (IoT) technologies and machine learning to support continuous health monitoring and automated classification of healthcare conditions. This study proposes an intelligent IoT-based healthcare monitoring approach using the IOT-ONN model for health-condition classification. The proposed approach is evaluated using four healthcare datasets obtained from the UCI Machine Learning Repository, namely SPECT Heart, Liver Disorders, Breast Cancer Wisconsin, and Thyroid Disease, covering both binary and multiclass classification problems. The datasets are processed using Python, and the performance of the proposed IOT-ONN model is assessed using ten-fold cross-validation. Its classification performance is compared with Artificial Neural Network (ANN), Naive Bayes, K-Nearest Neighbour, Support Vector Machine, and Decision Tree classifiers. The results demonstrate that IOT-ONN provides improved performance over the conventional ANN model across all selected datasets and achieves competitive classification performance compared with other established machine learning algorithms. The findings indicate that integrating IoT-based healthcare monitoring with intelligent learning models can provide an effective framework for automated health-condition classification and support the development of smart healthcare systems.
Keywords: Smart Healthcare Monitoring, Internet of Things, Machine Learning, IOT-ONN, Artificial Neural Network

1. INTRODUCTION

Smart Healthcare Monitoring (SHM) has become an important approach for improving the continuous observation and management of patient health. Traditional healthcare systems generally depend on periodic clinical examinations and manual monitoring, which may not provide continuous information about changes in a patient's health condition. Smart monitoring systems overcome this limitation by enabling health-related information to be collected and analyzed continuously.[1] The integration of intelligent technologies allows healthcare providers to obtain timely information and support the early identification of abnormal health conditions. SHM can therefore improve the efficiency, accessibility, and responsiveness of healthcare services while supporting remote monitoring and personalized patient care.[2]

The Internet of Medical Things (IoMT) plays an important role in the development of smart healthcare monitoring systems.[3] IoMT connects medical devices, sensors, wearable technologies, communication networks, and healthcare applications to facilitate the collection and exchange of patient health information. IoT sensors can collect physiological parameters and other health-related information from patients and transmit the acquired data for further processing and analysis.[4] The integration of IoMT with intelligent computational techniques allows healthcare data to be transformed into useful information for monitoring and classification. This connected environment supports continuous patient observation and provides opportunities for remote healthcare services, particularly when direct and frequent clinical supervision is difficult.[5]

Deep Learning (DL) has become an important technology in smart healthcare because of its ability to identify complex patterns from large amounts of healthcare data.[6] DL models can be used to analyze physiological information and assist in the identification and classification of different health conditions. Machine learning and deep learning can provide automated analysis of data collected through IoT-enabled healthcare devices, thereby reducing dependence on manual interpretation.[7] However, the use of intelligent learning techniques in healthcare also involves several challenges, including the availability and quality of healthcare data, computational requirements, data heterogeneity, model complexity, and privacy concerns. Transfer learning can help address limited training-data problems by utilizing knowledge obtained from previously trained models.[8] Nevertheless, differences between datasets and healthcare environments can affect the effectiveness of transferred knowledge. These challenges demonstrate the need for efficient and adaptable intelligent models for smart healthcare monitoring.

Smart Healthcare Monitoring has a wide range of applications in modern healthcare.[9] It can be used for continuous physiological monitoring, patient observation, remote healthcare, stress monitoring, disease classification, and early identification of abnormal health conditions.[10] Wearable and IoT-enabled devices allow health information to be collected without requiring patients to remain continuously within clinical environments. The collected information can subsequently be analyzed using machine learning and deep learning techniques to identify relevant health patterns. Such systems can provide several benefits, including real-time monitoring, remote accessibility, automated health assessment, faster identification of potential health problems, and improved healthcare efficiency.[11] The integration of intelligent data analysis with connected sensing technologies can therefore support the transition from conventional healthcare monitoring toward more proactive and technology-driven healthcare services.

The increasing use of IoT devices in healthcare has resulted in the generation of large volumes of patient-related data. However, collecting health information alone is insufficient unless the data can be effectively analyzed and converted into meaningful health information.[12] An intelligent healthcare monitoring system should therefore combine IoT-based data acquisition with machine learning techniques capable of classifying health conditions accurately. Such integration can provide a framework for continuous monitoring, automated analysis, and intelligent health-condition classification. In this context, the development of an IoT-based intelligent model can improve the effectiveness of healthcare monitoring across different types of healthcare datasets. Therefore, this study focuses on the IOT-ONN model for health-condition classification and evaluates its performance using four healthcare datasets, namely SPECT Heart, Liver Disorders, Breast Cancer Wisconsin, and Thyroid Disease. The performance of the proposed model is further compared with conventional machine learning algorithms to assess its effectiveness for intelligent healthcare monitoring.

2. RELATED WORKS

Rahman et,al (2024) In recent years, machine learning (ML) and deep learning (DL) have been the leading approaches to solving various challenges, such as disease predictions, drug discovery, medical image analysis, etc., in intelligent healthcare applications. Further, given the current progress in the fields of ML and DL, there exists the promising potential for both to provide support in the realm of healthcare. This study offered an exhaustive survey on ML and DL for the healthcare system, concentrating on vital state of the art features, integration benefits, applications, prospects and future guidelines. To conduct the research, we found the most prominent journal and conference databases using distinct keywords to discover scholarly consequences. First, we furnished the most current along with cutting-edge progress in ML-DL-based analysis in smart healthcare in a compendious manner. Next, we integrated the advancement of various services for ML and DL, including ML-healthcare, DL-healthcare, and ML-DL-healthcare. We then offered ML and DL-based applications in the healthcare industry. Eventually, we emphasized the research disputes and recommendations for further studies based on our observations.[13]

Nasr et,al (2021) The significant increase in the number of individuals with chronic ailments (including the elderly and disabled) has dictated an urgent need for an innovative model for healthcare systems. The evolved model will be more personalized and less reliant on traditional brick-and-mortar healthcare institutions such as hospitals, nursing homes, and long-term healthcare centers. The smart healthcare system is a topic of recently growing interest and has become increasingly required due to major developments in modern technologies, especially artificial intelligence (AI) and machine learning (ML). This paper is aimed to discuss the current state-of-the-art smart healthcare systems highlighting major areas like wearable and smartphone devices for health monitoring, machine learning for disease diagnosis, and the assistive frameworks, including social robots developed for the ambient assisted living environment. Additionally, the paper demonstrates software integration architectures that are very significant to create smart healthcare systems, integrating seamlessly the benefit of data analytics and other tools of AI. The explained developed systems focus on several facets: the contribution of each developed framework, the detailed working procedure, the performance as outcomes, and the comparative merits and limitations. The current research challenges with potential future directions are addressed to highlight the drawbacks of existing systems and the possible methods to introduce novel frameworks, respectively. This review aims at providing comprehensive insights into the recent developments of smart healthcare systems to equip experts to contribute to the field.[14]

Rajan Jeyaraj et,al (2022) Automated physiological signal monitoring to elderly sick patient is not only for fast access of data but also to get reliable service by accurate prediction by healthcare service provider. To address this challenge, this research focuses on novel Internet of Things (IoT) application-based physiological signal monitoring system to advance e-healthcare system. For the realization of the proposed system, Deep Neural Network-based accurate Signal Prediction and estimation algorithm was employed. The proposed system is prototyped as an advanced electronics component by using an intelligent sensor for signal measurement, National Instrument myRIO for smart data acquisition. Smart-Monitor is designed with intelligent sensor as the consumer product. To validate the proposed Smart-Monitor system, four physiological signal prediction accuracies for two users were computed. In prototype experimental set-up, an average accuracy of 97.2% was obtained. This shows that the proposed automated system is reliable and accurate monitoring is possible. From the experimental result, we validate the proposed system can provide reliable assist and accurate signal prediction.[15]

Sujith et,al (2022) In the rapidly growing world of technology and evolution, the outbreak and emergences diseases have become a critical issue. Precaution, prevention and controlling the diseases by technology has become the major challenge for healthcare professionals and health care industries. Maintaining a healthy lifestyle has become impossible in the busy work schedules. Smart health monitoring system is the solution to the above poses challenges. The recent revolution of industry 5.0 and 5G has led to development of smart cum cost effective sensors which help in real time health monitoring or individuals. The SHM has led to fast, cost effective, and reliable health monitoring services from remote locations which was not possible with traditional health care systems. The integration of blockchain framework improved data security and data privacy of confidential data of patient to prevent the data misuse against patients. Involvement of Deep Learning and Machine learning to analyze health data to achieve multiple targets has helped attain preventive healthcare and fatality management in patients. This has helped in the early detection of chronic diseases which was not possible recently. To make the services more cost effective and real time, the integration of cloud computing and cloud storage has been implemented. The work presents the systematic review of SHM along with recent advancements in SHM with existing challenges.[16]

Krishnamoorthy et,al (2023) One of the most significant phases of human life is health. Every society is paying more consideration to and implementing knowledge in the areas of health and healthcare. Artificial intelligence (AI) is increasingly being used in the healthcare industry to provide accurate and rapid outcomes. Predictions about the onset of disease help doctors save the lives of their patients by intervening early. Smart health monitoring systems are becoming a reality thanks to the IoT. The IoT is functioning as a catalyst for artificial intelligence applications in healthcare. IoT sensors collect patient information, which is then analyzed with machine learning (ML) programs. In this chapter, we present a novel and intelligent healthcare monitoring system based on cutting-edge technologies like the IoT, optimization methods, and machine learning, with the goal of providing early and accurate diagnosis of a wide range of diseases. In this section, we examine the pros and cons of several IoT and ML-based healthcare monitoring systems. ML strategies are utilized to make predictions based on the medical sensor data that has been uploaded to the cloud. Using data from the UCI repository, this chapter describes the common frameworks for developing AI-based machine learning techniques for the Internet of Things.[17]

Islam et,al (2020) Healthcare monitoring system in hospitals and many other health centers has experienced significant growth, and portable healthcare monitoring systems with emerging technologies are becoming of great concern to many countries worldwide nowadays. The advent of Internet of Things (IoT) technologies facilitates the progress of healthcare from face-to-face consulting to telemedicine. This paper proposes a smart healthcare system in IoT environment that can monitor a patient's basic health signs as well as the room condition where the patients are now in real-time. In this system, five sensors are used to capture the data from hospital environment named heart beat sensor, body temperature sensor, room temperature sensor, CO sensor, and CO2 sensor. The error percentage of the developed scheme is within a certain limit (< 5%) for each case. The condition of the patients is conveyed via a portal to medical staff, where they can process and analyze the current situation of the patients. The developed prototype is well suited for healthcare monitoring that is proved by the effectiveness of the system.[18]

Poongodi et,al (2021) Recently, the development of building a smart city has been inclined rapidly with the help of emerging technologies in 5G and internet of things (IoT). In addition with smart city, concepts of smart traffic systems and smart health are also being developed. Combining the above two, smart navigation system for ambulances is being coined. When critical patients are referred by an ambulance, there is a lot of time wastage in facilitation of information and the hospital is completely unaware of the patient's parameters who is arriving beforehand. Therefore, patient monitor and ambulance tracking system is an efficient system used to carry out a quick thirty-second diagnosis using heartbeat, temperature, breath rate sensors to record vital patient parameters required initially by the doctors to start any treatment and remotely transmit these parameters over wireless medium to the hospital even before the ambulance is deployed. The patient also gets an instant way to request an ambulance on touch of a button without having to call up the hospital and also instantly send a short message service (SMS) to an emergency contact giving both the hospital and contact necessary emergency details a lot earlier. This saves a lot of time, each second of which is important to the patient at life risk. The patient can keep a track of the ambulance's location, which gives them an idea of its arrival and can also get instant navigation toward the nearest hospital for themselves if need be. The device can be kept with the patient and also installed inside the ambulance. The device enables the use of IoT sensors and android applications for better user interaction and efficient information transmission. The model dictated here is potentially outperformed with easiness and in a better way toward smart healthcare monitoring services.[19]

Badiganti et,al (2022) With growing health awareness and the increasing cost of medical care, there is an impetus to new and advanced technologies for disease prevention and early diagnosis and treatment. The weakest link exposed by the COVID-19 pandemic in India is health care. Investment in critical health Infrastructure aided by modern technology is the need of the hour. So, this project aims to develop a comprehensive healthcare monitoring system by blending IoT and VLSI. It can monitor a patient's basic health signs as well as the room condition where the patients are now in real time. We use Nexys4 Artix7 as a processor. In this system, six sensors are used to capture the data from the hospital environment named heartbeat sensor, body, and room temperature sensor, fall detection sensor, blood pressure sensor, air quality monitoring sensors, ECG sensor. [20]

Begum et,al (2020) Recently, the implementation of Raspberry Pi controlled monitor system performs well defined medical applications for diagnosis of DCM Healthcare. The development of IoT (Internet of Things) is an important application domain in medical field that draws huge interest from industry, research field and public sector. In medical applications, the temperature and humidity data are often major considerations. The main objective of this framework is to give immediate necessary services where cardiac patient can measure body temperature, heart rate in bpm and body position by themselves and promote hygienic environment. The framework is tested for a volunteer to check the body temperature, heart rate and observe the movement of body position and view the ECG graph using Serial Plotter Software on a local server.[21]

Alekya et,al (2021) In the main process, research into health requests is immovable among the different requests of IoT. Healthcare requests generally reflect close attention to IoT techniques due to cost savings, ease of interpretation, and recovery of patients personal satisfaction. This paper helps to imagine how IoT can be incorporated into complex health care procedures. The "Mobile Healthcare Management System (HMS)" is one of the main IoT apps that link the Internet to mobile sensors, people, clinicians, networks and other connected devices. The failed method, the IoT-based smart HMS, has made it possible for clinicians to monitor their patients in remote areas on an ongoing basis. The Internet of Things cooperates with numerous technologies, such as the Wireless Sensor Network (WSN), which communicates with each other through Coap, 6LoWPAN, REST and other protocols, such as radio frequency data, smart mobile inventions and wireless sensor networks.[22]

Research Gap: Although previous studies have demonstrated the potential of machine learning, deep learning, IoT, and wearable technologies for smart healthcare monitoring, several gaps remain. Existing research has largely focused on reviewing healthcare applications, developing wearable monitoring systems, or applying individual intelligent learning techniques to specific healthcare problems. Many studies emphasize physiological signal monitoring or particular health conditions, while comparatively less attention is given to a unified classification approach that can be evaluated across different healthcare datasets. In addition, existing IoT-based healthcare frameworks often concentrate on data acquisition and remote monitoring, with limited emphasis on systematically comparing an IoT-oriented intelligent model with multiple conventional machine learning classifiers. The use of diverse healthcare datasets containing both binary and multiclass classification problems also requires further investigation to determine the consistency of intelligent models across different healthcare conditions. Therefore, there is a need for an intelligent IoT-based healthcare monitoring approach that combines health-data acquisition with effective classification and evaluates its performance across heterogeneous healthcare datasets. To address this gap, the present study develops and evaluates the IOT-ONN model using multiple UCI healthcare datasets and compares its classification performance with ANN and other established machine learning algorithms.

3. OBJECTIVE OF THE STUDY

- To collect patient health data utilizing IoT sensors.
- To classify health conditions using the IOT-ONN model.
- To analyze the proposed model utilizing UCI healthcare datasets.
- To compare the proposed model with existing machine learning algorithms.

4. PROPOSED METHODOLOGY

The proposed methodology consists of two main stages: data collection and the learning and prediction process. In the data collection stage, four healthcare datasets, namely SPECT Heart, Liver Disorders, Breast Cancer Wisconsin, and Thyroid Disease, are obtained from the UCI Machine Learning Repository. The datasets contain different numbers of healthcare attributes and classification categories, allowing the proposed approach to be evaluated across both binary and multiclass healthcare problems. The collected datasets are prepared and organized for classification analysis using Python. In the learning and prediction stage, the datasets are provided to the classification models, including the conventional Artificial Neural Network (ANN) and the proposed IOT-ONN model. Ten-fold cross-validation is employed to assess the consistency of the models, where the data are divided into ten subsets, with nine subsets used for training and the remaining subset used for testing. The process is repeated so that each subset is used once for testing. During the learning process, the models identify patterns within the healthcare data and generate predictions for the corresponding health-condition classes. The performance of the proposed IOT-ONN model is then evaluated using classification accuracy and training time. In addition, the proposed model is compared with ANN, Naive Bayes (NB), K-Nearest Neighbour (K-NN), Support Vector Machine (SVM), and Decision Tree (DT) classifiers to determine its effectiveness for healthcare-condition classification. The overall methodology therefore provides a systematic framework for evaluating the ability of the IOT-ONN model to support intelligent and automated healthcare monitoring.

5. RESULTS AND DISCUSSIONS

In this section, the results of different classification algorithms, including ANN and IOT-ONN, are discussed and analyzed. The proposed IOT-ONN model is evaluated using four healthcare datasets obtained from the UCI Machine Learning Repository. These datasets include SPECT Heart, Liver Disorders, Breast Cancer Wisconsin, and Thyroid Disease. The characteristics of the datasets used in the study are presented in Table 1. Python is used for the implementation and evaluation of the classification models.

Table 1. Dataset Characteristics

Dataset	No. of Features	No. of Samples	No. of Classes	Classification Type
SPECT Heart (SCTH)	22	267	2	Binary
Liver Disorders (LD)	5	345	2*	Binary*
Breast Cancer Wisconsin (BCW)	9	699	2	Binary
Thyroid Disease (TD)	5	7,200	3	Multi

Training time and accuracy are considered as the two performance indicators for evaluating the effectiveness of the classifiers. Training time represents the total time required during model training, while accuracy represents the proportion of correctly classified samples. Accuracy is calculated using Equation (1).

$$Accuracy\ (Acc) = \frac{Number\ of\ correctly\ classified\ samples}{Total\ number\ of\ samples\ in\ the\ testing\ dataset} \times 100 \quad (1)$$

Both the ANN and proposed IOT-ONN models are trained using ten-fold cross-validation. The dataset is divided into ten subsets, with nine subsets used for training and one subset used for testing. This process is repeated ten times so that each subset is used once for testing. The results obtained from the four healthcare datasets are presented in Table 2.

Table 2. Dataset-Based Accuracy Comparison of ANN and IOT-ONN Models

Fold	SCTH ANN	SCTH IOT-ONN	LD ANN	LD IOT-ONN	BCW ANN	BCW IOT-ONN	TD ANN	TD IOT-ONN
1	78.52	92.18	80.85	91.24	80.41	95.16	87.92	96.14
2	76.85	91.47	82.14	90.63	81.24	94.72	88.41	96.52
3	79.63	93.25	81.52	92.18	80.67	95.83	87.68	96.21
4	77.94	92.64	82.36	91.72	81.05	95.27	88.73	97.04
5	80.16	93.18	81.27	91.45	80.92	94.86	87.54	95.87
6	77.42	91.83	82.05	92.37	81.36	95.41	88.25	96.73

7	79.05	92.71	81.43	91.84	80.58	95.62	88.96	96.48
8	78.21	92.06	81.76	91.38	81.17	95.08	87.81	96.35
9	77.68	91.95	82.21	92.05	80.74	95.34	88.37	96.82
10	80.10	93.18	81.77	91.96	81.85	95.64	88.84	96.79
Average	78.56	92.45	81.74	91.68	81.00	95.29	88.45	96.50

The results in Table 2 show that the IOT-ONN model achieves higher accuracy than ANN across the four datasets. The average accuracy of IOT-ONN is 92.45% for SPECT Heart, 91.68% for Liver Disorders, 95.29% for Breast Cancer Wisconsin, and 96.50% for Thyroid Disease.

Table 3. Accuracy Comparison of Diverse Classifiers with Various Datasets

Dataset	ANN (%)	NB (%)	K-NN (%)	SVM (%)	DT (%)	IOT-ONN (%)
SPECT Heart	78.56	84.72	88.16	91.83	89.76	92.45
Liver Disorders	81.74	72.86	75.61	77.43	71.95	91.68
Breast Cancer Wisconsin	81.00	90.87	95.74	97.02	93.91	95.29
Thyroid Disease	88.45	81.94	83.82	84.56	82.71	96.50

The results indicate that IOT-ONN provides competitive performance across the selected datasets. It achieves the highest accuracy for SPECT Heart, Liver Disorders, and Thyroid Disease. For the Breast Cancer Wisconsin dataset, SVM records slightly higher accuracy than IOT-ONN, while the proposed model still provides strong performance.

The final comparison considers the accuracy of IOT-ONN against existing machine learning models. The comparative results are presented graphically in Fig. 1.

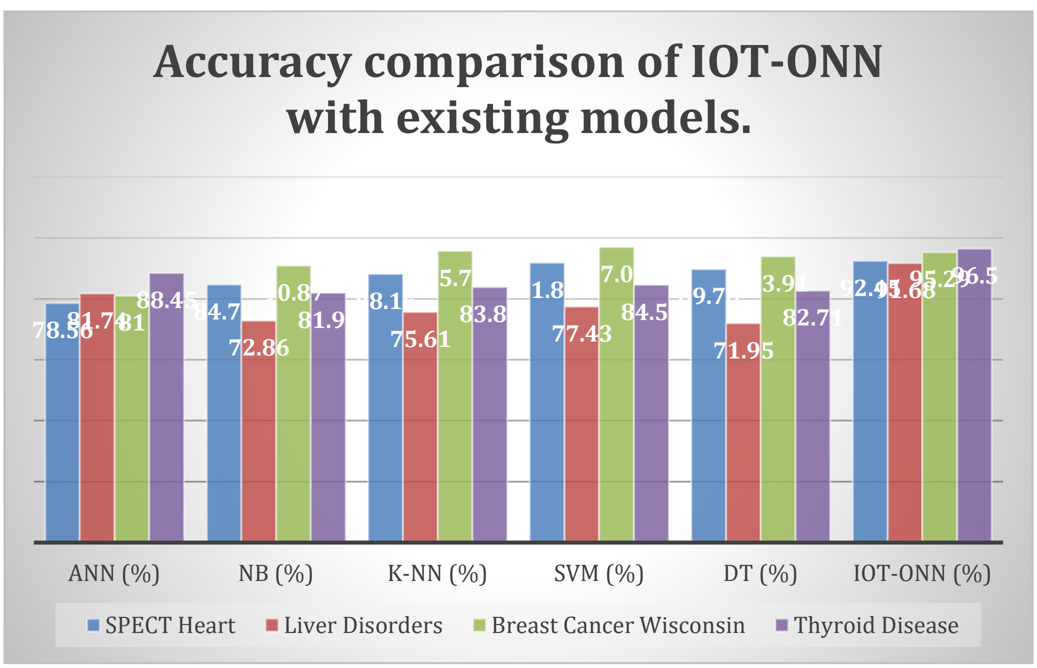

Fig 1: Accuracy comparison of IOT-ONN with existing models.

The comparison shows that the proposed IOT-ONN model provides competitive classification performance across different healthcare datasets. Its performance across both binary and multiclass datasets indicates its potential for intelligent healthcare monitoring and automated health-condition classification.

Overall, the results indicate that the proposed IOT-ONN model performs better than conventional ANN and provides competitive performance compared with other machine learning classifiers. Further fine-tuning of model and optimization parameters can be considered to improve classification accuracy and computational efficiency.

6. CONCLUSION

The study concludes that the proposed IOT-ONN model provides an effective approach for intelligent healthcare monitoring and automated health-condition classification. The model was evaluated using multiple healthcare datasets and ten-fold cross-validation to assess its classification capability. The findings demonstrate that IOT-ONN performs better than the conventional ANN model and provides competitive performance compared with other machine learning classifiers, including Naive Bayes, K-NN, SVM, and Decision Tree. The results indicate that integrating intelligent learning techniques with IoT-based healthcare monitoring can support reliable analysis and classification of healthcare data. The proposed approach can contribute to the development of smart healthcare systems by enabling automated health-condition assessment and supporting more efficient monitoring. In future work, the model can be further enhanced through optimization and parameter tuning, evaluation using larger and real-time healthcare datasets, integration with physical IoT sensors and wearable devices, and assessment using additional performance measures to improve its reliability, efficiency, and practical applicability in real-world healthcare environments.

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