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A Promising Smart Healthcare Monitoring Model based on Internet of Things and Deep Learning Techniques

Marwa Abdulrahman Al-Hadi[1] *, Ghaleb Hamoud Al-Gaphari[1], Ibrahim Ahmed Al-Baltah[2,3] and Francisco Bacallao Julian[4]

[1]**Department of Computer Science, Faculty of Computer Science and IT, Sana'a University, Sana'a, Yemen,**
[2]**Department of Information Technology, Faculty of Computer Science and IT, Sana'a University, Sana'a, Yemen,**
[3]**Department of Information Technology, Faculty of Science and Engineering, Al-Hikma University, Sana'a, Yemen,**
[4]**4Consultant cardiovascular surgeon in Cardiac -Center, Military Hospital, Sana'a, Yemen.**

*Corresponding author: marwa.alhadi@su.edu.ye

Abstract

Using Internet of Things (IoT) and deep learning techniques in the healthcare sector has gained significant momentum in recent years. These technologies have the potential to transform traditional healthcare monitoring systems into real-time data collection, analysis, and decision-making capabilities. While several models have been developed to assist people with heart diseases, numerous obstacles still impede the effectiveness of the current solutions, such as power consumption, latency, accuracy, and scalability. Therefore, this study aims to develop a promising smart healthcare monitoring model that integrates IoT and deep learning techniques for saving patient lives. In addition, it clarifies the current research gap. The methodology used in this study was a literature review, which was conducted to identify relevant studies on IoT and deep learning applications in healthcare and find the gaps in each. This model consists of three main components: data acquisition through IoT devices, data processing using deep learning algorithms, and decision-making based on analyzed data. Moreover, it showed an unstable rate of accuracy in the current studies, which were taken from 2021 to 2023. In the future, our proposed smart healthcare monitoring model will solve that gap, which is already available in the current studies, and that will be proven using real-time materials such as Arduino and heart disease sensors.

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1. INTRODUCTION

With the acceleration that has occurred recently in our daily lives, let us think about the available technology that will facilitate human life [1]. The Internet of Things (IoT) is one of these technologies that plays a significant role in changing the traditional way of life into a high-tech lifestyle [2]. According to recent research, the number of IoT devices getting connected to the Internet is exponentially increasing, roughly reaching 75 billion by 2025 [3]. The number of studies in IoT from 2000 to 2019 was about 9589, and numerous challenges need further research to tackle them [4]. Since the appearance of IoT, many researchers have attempted to define it from different perspectives [5]. However, one of the accepted definitions is that IoT is a mechanism for sharing data between devices via sensors, actuators, communication technologies, and big data analytics that is connected using the original architecture and includes two layers: the client side, which is represented by the user, and the server side, which is represented by the cloud [6, 7]. Due to this architecture, the problems of latency, power consumption, device heterogeneity, interoperability, communication, bandwidth, energy availability, security, privacy, scalability, energy efficiency, lack of standard protocols, etc. create a gap in IoT [5, 8]. Therefore, many researchers have attempted to explore, discuss, and find new techniques that help in enhancing and developing a solution for the existing gap [9, 10]. The impact of IoT is not required only in one field; it is already embedded in multiple fields, including healthcare systems, smart homes, smart cities, energy savings, smart transportation, pollution control, and smart industries [2]. Hence, the field of healthcare systems is only covered by 29% of studies in general research fields, whereas home studies are covered by 67% [11]. In addition, among all the diseases that spread around the globe, heart disease is the top one globally. The number of deaths around the world was about 8.9 million in 2019, which represents a person dying every few seconds [12, 13]. A set of alternative solutions is suggested in healthcare research. Deep learning is one of the most common techniques used in healthcare systems to improve the precision of diagnosis. Deep learning is defined as a branch of machine learning that gives artificial intelligence the upper hand. It will attempt to become closer to its ultimate goal [14].

Therefore, our contributions can be summarized as follows:

- Presented a different model that was used to monitor heart disease based on IoTs and deep learning techniques.
- Present the limitations of each model and how to cover these limitations in the suggested model.
- Presented a promising smart model for monitoring heart disease based on IoTs and deep learning techniques.
- Presented the level of accuracy in heart disease diagnosis from 2021 until 2023.

2. PROBLEM STATEMENT

Among all the diseases that people suffer from around the globe, heart disease is the top global disease. The number of deaths around the world was about 8.9 million in 2019, which represents a person dying every few seconds [12, 13]. Many models have been designed to serve human beings in terms of heart diseases; unfortunately, the available solutions are still plagued by many challenges: scalability, accuracy, long-term response, power consumption, network bandwidth and latency, etc. [15]. Meanwhile, there is no optimal healthcare model for monitoring and diagnosing heart disease based on IoT and deep learning techniques, and it seems that researchers shared many technical solutions, some of which were presented in the related work, whereas there is still no ideal model for the healthcare system [8].

A set of alternative solutions is suggested for precise diagnosis results for patients using deep learning in the IoT. Even though they try to reduce latency and energy for data processing and increase the level of accuracy in data prediction results, the rate of accuracy is still between 89 and 94, and their model latency is between 29.8 and 2610.8 milliseconds [11]. At the same time, [13] fully employs convolutional neural networks (CNN) to perform real-time heart-related disease detection. The accuracy increases to over 0.96 for very small sizes of data, while increasing the size of data will result in a lack of result. Therefore, the main problem of the healthcare models within the IoT environment is low performance in terms of the factors stated above (scalability, accuracy, long-term time response, power consumption, network bandwidth, and latency).

3. RESEARCH MOTIVATION

Due to these shortcomings, which have already been discussed in the problem statement and previous studies, the need for this study has become a necessity, and it will move this field of research to a further point based on a set of objectives in the form of:

1 Reduce the number of dead people by eliminating the limitations of the prior studies on performance and its main terms, such as scalability, accuracy, long-time response, power consumption, network bandwidth, and latency, via building a model based on the Internet of Things and deep learning techniques.

2 Save people's lives via the design of a predictor for predicting patient status, which includes a set of modules to maximize scalability and accuracy while minimizing long-term response, power consumption, and latency. Thus, it will help in having an accurate diagnosis in a short period of time.

4. RESEARCH QUESTIONS

The main question that should be solved in this research is how to build a smart healthcare monitoring model based on IoTs and deep learning techniques. The above question will be discussed in a set of questions as follows:

1 How to conduct data pre-processing

1.1 How to filter data
1.2 How to select more relevant features
1.3 How to remove noise from data
1.4 How to remove the biases of classes

2 How to design a dedicated device for detecting patient status

2.1 How to design a module that will help maximize scalability
2.2 How to design a module that will help in maximizing accuracy
2.3 How to design a module that will help minimize long-term response
2.4 How to design a module that will help minimize

power consumption

2.5 How to design a module that will help reduce latency

3 How to implement an ensemble model for precise disease prediction

4 What are the techniques and methods that we should use for testing the proposed model?

5. RESEARCH OBJECTIVES

The main aim of this study is to build a smart healthcare monitoring model based on the Internet of Things and deep learning techniques. The above aim will be implemented through the following phases:

Phase one: pre-processing phase

- Conduct a pre-processing module that includes:
  - o Filter data
  - o Select more relevant features.
  - o Remove noise from the data.
  - o Remove biases from classes.

Phase two: Designing phase

- Design a dedicated space for the optimization of the following factors:

o Design a module that will help maximize scalability.

o Design a module that will help in maximizing accuracy.

o Design a module that will help minimize long-term responses.

o Design a module that will help minimize power consumption.

o Design a module that will help reduce latency.

Phase Three: Implementation phase

Implement the above dedicator based on a deep learning ensemble algorithm for detecting patient status.

Phase four: validation phase

Test the current model by using a set of measures and techniques.

6. RELATED WORK

Numerous studies have appeared to cover the concept of how technology deals with the healthcare system, industry, environment, energy, etc. Mostly, the answer to this question is obtained by having a set of case studies and trying them using the experimental method. Knowing that one of the most interesting fields is the healthcare system, which answers the question of whether technology helps reduce the number of deaths each year with the diagnosis process, These studies concentrated on how we could help people save their lives by preventing the disease in the early stages. Some studies are interested in the performance of the system; others focus on acceleration; and others concentrate on power consumption or accuracy [16].

As described in [17], the traditional architecture of IoT has three layers: the data collection layer, which captures the data via wearable devices, then filters the data, removes noise, manages power, and sends it via Bluetooth to the next layer, which is called data preprocessing; the net layer, which processes the data in cases of data dimension enhancement, data normalization, data transmission, and generating grayscale images, then sends it to the last layer, which is called data preprocessing; and the application layer, which uses a deep learning model, cloud server, and AI engine to predicate the status. The accuracy of this model is over 77.6%. CG and EEG signals are not used, which may enhance the prediction accuracy result. In [18], specific hardware is used as IoT tools for data acquisition, such as sphygmomanometer cuffs, temperature sensors, and pulse sensors, then data is sent to the STM32 controller to store and extract the exact data, and after that, a deep learning algorithm called curve fitting and regression analysis is used to process and give the final result. This work used only three types of sensors, which have only three factors to measure for prediction, which may reduce the precision of the prediction. This work applies to eighteen subjects, with only one woman included, which closes the door to having the result be the generality of the women.

In [19], his proposed work is divided into three sections: wearable devices and monitoring equipment, wireless communication relay networks, and health assessment and monitoring servers. The athlete has IoT-enabled sensing devices attached to their bodies, which routinely gather data and send it across a relay network to the server. The athlete has IoT-enabled sensing devices attached to their bodies, which routinely gather data and send it across a relay network to the server. Process and analysis via a set of algorithms.
Whereas in [20], having data via IoT devices where historical data is stored in the cloud for predictive analysis and using Bi-LSTM (bidirectional long short-term memory) for the final result of prediction that answers the question of does he or she has a heart disease or not.
In [21], more than one algorithm is used to increase the performance of the model that predicts diabetes disease, such as support vector machines (SVM), logistic regression, artificial neural networks (ANN), convolutional neural networks (CNN), recurrent neural networks (RNN), and long- and short-term memory (LSTM)—providing a healthcare model based on machine learning and deep learning on an IoT platform and monitoring a patient's health status in real-time by measuring two types of health condition metrics: biological and behavioral changes. Then the patient's health state is classified as normal or abnormal.
In [22],MRI data gathering, data processing, image

feature extraction, data training and testing, and then model creation. After that, data normalization using CNN is used to predict the outcome.

In [23], low latency, security, and high performance are the main points that were concentrated on by dividing the main IoT architecture into three layers. The first layer, called the IoT layer, concentrates on collecting data from sensors and sending it to the next layer, which transfers it through the local blockchain into the fog layer. In the second layer, it makes the first decision about whether the person has a critical situation or not by sending a message to each doctor and patient. In addition, all the information will be sent into the third layer, which includes the global blockchain and deep learning consensus algorithm, to analyze the situation and give a prediction.

In [24], a total of 1600 images of cardiac conditions are captured. The matrix's performance is assessed using metrics including execution time, bit error rate (BER), f-score, accuracy, and specificity. The suggested approach is examined and contrasted with the current algorithms, Support Vector Machine (SVM), Logistic Regression (LR), Multilayer Perception (MLP), and K-NN-NB. Additionally, data collection on Hungarian heart disease is provided as an input to the detection algorithm. Utilize the Internet of Things to foresee heart illness. The suggested system receives data on heart disease in Hungary as input, and preprocessing then occurs. The preprocessing is done using the median studentized residual technique. Preprocessed data is feature-selected. Utilizing Harris Hawk Optimization (HHO), features are chosen. Modified Deep Long Short-Term Memory is used to classify the data, and enhanced Spotted Hyena Optimization is used to modify it. Finally, the outcome is determined as either a normal or abnormal state.

This section will highlight techniques that are used to diagnose cardiovascular disease or any of its types, like using smart healthcare monitoring studies based on IoTs and deep learning. This study will describe a set of samples from 2021–2023, which will be represented in Tables 1 and 2.

7. METHODOLOGY

The proposed research methodology for this study will be done using a hybrid method that involves the following:
First: qualitative method:

- Conduction literature review about
  - o IoT
  - o Deep learning
  - o Heart disease
- Conducting a comparison of different studies that include smart healthcare systems for monitoring heart diseases based on IoT and deep learning techniques

Second, quantitative method:

- Build a model that detects patient status. Does he/she have heart disease or not via including a set of phases as follows:
  - o First: preprocessing phase
  - o Second: design phase
  - o Third: implementation phase
  - o Fourth: validation and testing phase

8. PROMISED MODEL

Due to the limitations that have already been found in the previous studies a promises model is conducted to cover all of these limitations which are represented in Fig. 1.

9. RESULT AND RECOMMENDATION

Numerous models have been built to serve human beings in terms of heart issues; nevertheless, the present solutions are still afflicted by numerous challenges such as scalability, accuracy, long-time response, power consumption, network bandwidth latency, etc. For example, in [17] concentrating on accuracy is the main factor, whereas power consumption is ignored. While [18], it concentrates on the simple size of the sample and makes it difficult to make a decision because of this small sample. In [19], accuracy and power consumption work on the opposite side, which deals with the number of neurons, increasing neurons, increasing power consumption, and enhancing performance. In [20], it ignored latency and bandwidth, which are obstacles to enhancing this model. In [21], delay could occur due to adding an edge to this model. In [22], time and bandwidth are critical points. In [23], more data means more latency.

From the above result that was collected, there is no stable result for accurate prediction, and it's still at risk of prediction. There are a few prediction factors, such as the sample size, etc., which are presented in Fig. 2.
Therefore, we recommend the following:

1. We recommend studying all the challenges that affect the heart disease prediction model or multiple measuring concepts such as scalability, accuracy, long-time response, power consumption, network bandwidth, and latency.
2. We recommend increasing the sample size because we deal with human life.
3. We recommend developing a real-time heart disease prediction model using real materials.

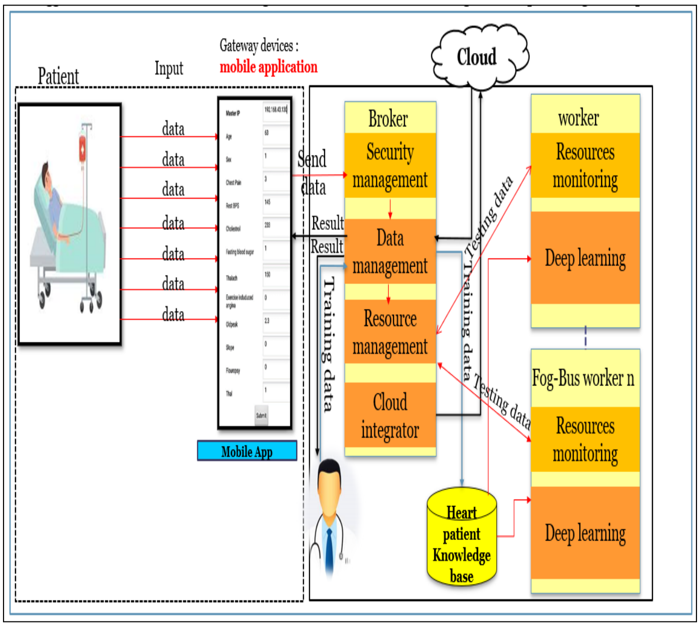

Figure 1. A promising smart Healthcare Monitoring Model based on IoTs and deep learning techniques

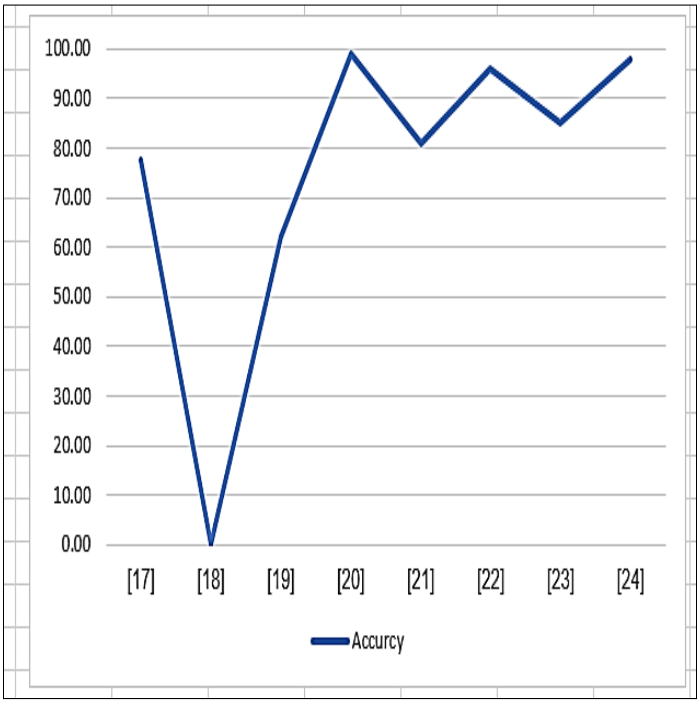

Figure 2. Result of the unstable rate of accurate prediction in the healthcare monitoring model based on IoTs and deep learning techniques

Therefore, coming studies will deal with the implementation of a healthcare monitoring model based on a set of factors and in real-time measures with real-time tools.

10. CONCLUSION

The Internet of Things (IoT) is a technology that has transformed traditional life into a high-tech lifestyle. The main issue with healthcare models is poor performance in terms of the following factors: scalability, accuracy, lengthy time response, power consumption, network bandwidth, and latency. As a result, our study is interested in promoting a smart healthcare monitoring model based on IoT and deep learning techniques. This study will be accomplished using a hybrid technique, which will include the following: (a) Comparing diverse research, including smart healthcare systems for monitoring cardiac disease. (b) Develop a promising predictor model for forecasting patient status using deep learning algorithms with a modular design to maximize scalability and accuracy. In the future, this model will be implemented using real-time data.

Table 1. Case studies in the field of Smart IoT systems to predicate cardiovascular disease using deep learning.

Ref.	Year	Methodology	Features	limitations
[17]	2021	First: Using a smartphone as a gateway in the stage of preprocessing and generating a grayscale map Second: having a cloud server carry the grayscale map using a deep learning algorithm called convolutional neural networks (CNN). Third: having volunteers generate the initial dataset	- Using CNN is a critical point of prediction which may help in accelerating the prediction process and getting the result.	- CG and EEG signals are not used. - small data storage capacity and low computing capacity.
[18]	2021	First, data is collected using a sphygmomanometer cuff, a temperature sensor, and pulse sensors. It was sent to the STM32 controller for storing data. Second: curve fitting and analysis via regression analysis and deep learning of data. It is taken and controlled via STM32 and has a curve that represents whether the person has valvular disease or not.	- Using STM32 may help in effectively controlling the process and extracting the exact information. - In addition, using LabVIEW software helps in specifying the result and representing it in an idle method.	- The blood pressure measurement system is not used as the main sensor. - The number of factors is only three, which may reduce the accuracy of a diagnosis. - There is no generality to this result for women because only one woman was included.
[19]	2021	This system is divided into three parts: First: wearable devices and monitoring equipment, which have wearable IoT devices that are connected to the body to gather information such as blood pressure, pulse, blood glucose, body temperature, heartbeat, dynamic monitoring of falls, and send it to the server via a network. Second: wireless communication relay networks using tiny OS to reduce power consumption and high performance. Third: health assessment and monitoring server: using a set of algorithms such as DNN and the Gradient Descent (GD) algorithm to predict the final result.	- Using a wireless sensor network managed via TinyOS, which reduces power consumption - After verification, the vital sign data from wearable sensor devices is immediately saved to the real-time medical health monitoring system.	- A few neurons may result in under-fitting issues since the model is sensitive to the number of neurons in the hidden layers. - An oversupply of neurons could exacerbate an overfitting issue. - Accuracy may increase with more hidden layers in a training or testing procedure. though, these increases will increase difficulties which will increase complexity and processing costs.
[20]	2022	It works as: First: Data collected via IoT devices Second: data preprocess and clean filter in the cloud layer. Third: cleaned and ensured data was sent to fuzzy information system for initial classification Fourth: Bi-LSTM is used for accuracy prediction.	- Accurate	- Adding the concept of fog/edge layers may enhance the performance of this work - This model needs to concentrate on latency and bandwidth.
[21]	2022	The process is done as follows: 1. An IoT sensor captures the data from the patients, 2. Machine learning and deep learning techniques are utilized to evaluate the data and forecast the existence of the deadly condition.	- Six machine learning and deep learning techniques were examined to give an accurate result.	- Delays may happen according to this methodology. - Advocate an edge-based data processing system to move computation and data storage closer to the patient's location to increase emergency reaction time and conserve system bandwidth.
[22]	2022	The methodology in this study is as follows: First: the collection of data from diverse sources Second: pre-processing data Third, remove noise. Fourth, normalize the data. Fifth: using CNN to predict the result	- Accuracy is high and dependable for the prediction due to the image processing method.	- Time and bandwidth are risk points in this model.
[23]	2023	It draws attention to its three-layer design as follows: First, the IoT device layer collects medical vital signals via sensors and sends them to the next layer, which is called fog. Second: the fog computing layer: received data stands in the fog; the analysis of the basic situation if it's in trouble sends a message to the patient and doctor to make the right decision. It keeps data in the local blockchain via a gateway and sends it to the global blockchain that is related to the cloud. Third: The Cloud Computing Layer: Data analytics and long-term data storage are handled by this layer. This layer allows for implementing sophisticated AI and deep learning algorithms for data categorization, disease diagnosis and prediction, and treatment.	- Low latency - High performance - Secure	- Having a huge amount of data will increase the latency.
[24]	2023	This work is done as follows: First: Information gathered about patients via IoT sensor devices Second, to resolve missing values, the input dataset is preprocessed using the median studentized residual method. Third: The Harris Hawk Optimization (HHO) technique uses preprocessed data values to choose features. Fourth: Modified Deep Long Short-Term Memory (MDLSTM) Fifth, it divides the chosen traits into normal and abnormal categories. Sixth: The Improved Spotted Hyena Optimization (ISHO) method is used to modify the LSTM output.	- Use more than evaluation matrices to exact the result, such as specificity, sensitivity, F-Score, Kappa value, accuracy, BER, and execution time..	- This study may be further developed by developing novel strategies for predicting heart disease in advance by examining early genetic and health status characteristics and precautions.

Table 2. Case studies details related to the samples represented in Table 1.

Ref.	Case study	Dataset	Algorithms	Accuracy	Other features	Wearable devices/others	Communication protocol	Evaluation matrix
[17]	Cardiovascular Disease	Private (generated from doctors in real hospitals in 100 days with 3000 historical data in China)	CNN	77.6%	Not mentioned	the blood pressure meter, weight/fat meter, pedometer, thermometer, and other data acquisition devices	Bluetooth	Accuracy, recall, precision, F1_score,
[18]	Valvular disease	Private (training set taken from historical data).	Regression analysis	Real-time results based on the situation. It catches 18 people for studying their status.	Fast processing with STN32. Take 5 minutes to give the result.	sphygmomanometer cuff, temperature sensor, and pulse sensors, STM32 controller.	It could work via cable or WiFi.	Mathematical model
[19]	Brain tumors, heart disease, cancer for athlete	Sanda athletes	DNN, the Gradient Descent (GD) algorithm	51 -73%	Reduce power consumption and high performance according to the use of TinyOS.	The chest strap sensor integrates an ECG and acceleration sensor, and the wrist strap sensor imitates blood oxygen saturation.	Wireless connection.	Precision, recall, AUC, and F1
[20]	Heart disease	Hungarian dataset	Bi-LSTM	98.86%	----------	Wearable blood pressure monitors and wearable ECG monitors equipped with medical sensors.	Bluetooth/Zigbee and WIFI	Accuracy, precision, specificity, recall, and F1 score
[21]	Diabetes and any other disease could deal with this model.	diabetes dataset obtained from the Kaggle data center	SVM, logistic regression, ANN, CNN, RNN, and LSTM to generate the best prognosis.	81%	----------	Body temperature sensors, sweat sensors, heart rate monitors, glucose monitors, and echocardiogram monitors	Wireless connection.	accuracy, F1-score, and recall
[22]	Heart Disease	MRI datasets	CNN	~96 %	----------	MRI is a precious tool scanning.	Wireless connection	Accuracy
[23]	Heart disease	Conceptual framework	Consensus algorithm	Enhanced by 40% compared to other models	low latency, security, and high performance efficient response time	Healthcare sensors	6LoWPAN, Zigbee	Conceptual framework
[24]	Heart disease	Hungarian dataset	(SVM), (LR), (MLP), K-NN-NB, and MDLSTM	: 98.01%	The reduced error rate of 91.11 reduced execution time.	Smartwatch AD8232 Pi with sc1272	Internet-connected devices	sensitivity, F-Score, Kappa value, accuracy, BER, and execution time.

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