Machine Learning-Based Prediction of Diabetes Mellitus Using Distributed Data Processing with Hadoop MapReduce

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Abstract: Diabetes mellitus is one of the most rapidly increasing chronic diseases in today's world, and early diagnosis is crucial to prevent complications and to otherwise improve the health of patients with the condition. With the expansion of clinical and health information and the complexity of data processing, traditional machine learning models have struggled to meet the growing demand. The explosion of clinical data and health records has positioned new challenges for old machine learning models in the face of mounting data quantities and processing demand. In this paper, a machine learning-based approach for diabetes prediction is introduced based on distributed data processing approach with Hadoop MapReduce is presented. The data pre-processing methods, feature engineering techniques, Hadoop Distributed File System (HDFS), MapReduce-based parallel processing, and supervised machine learning algorithms are also suitable for addressing the challenges of analyzing large healthcare datasets. The data pre-processing methods, feature engineering techniques, Hadoop Distributed File System (HDFS), MapReduce-based parallel processing and supervised machine learning algorithms are also suitable for addressing these challenges. The distributed design helps fast training of models and prediction, with a high classification performance. Through the experimental evaluation, it is proven that the proposed framework achieves computational efficiency, scalability, and the accuracy of the predictions as compared to the traditional centralized approaches. The proposed solution offers a scalable and reliable architecture for intelligent healthcare analytics and real-time, clinical decision support.
Keywords: Diabetes Mellitus, Machine Learning, Hadoop MapReduce, Distributed Data Processing, Big Data Analytics, Healthcare Prediction, Classification.

Introduction:

Diabetes mellitus is a chronic metabolic disorder in which blood sugar levels are increased due to reduced insulin production or the inadequate use of insulin. Global health reports indicate that diabetes continues to rise, with a pronounced burden on healthcare systems and the importance of timely diagnosis and proper management of the disease have grown. Precise prediction of diabetes allows healthcare providers to spot individuals who are at risk and take a proactive approach to diabetes prevention.

With the popularisation of EHR, wearable technology, lab systems and medical imaging, immense amounts of healthcare data are now inundating the healthcare system. While machine learning algorithms have proven successful in predicting disease health issues, traditional single-machine static architectures can be constrained in that they can be slow to run and have significant compute requirements, and can not be easily scaled to process large data sets.

Distributed computing technologies offer an efficient approach to dealing with "healthcare big data. One of the components in the Hadoop distributed technology is the Hadoop Distributed File System (HDFS) for distributed file storage and the MapReduce programming model for distributed data processing. Hadoop spreads out the computation among nodes which leads to much faster processing times, higher system scalability and fault tolerance.

The paper introduces a distributed machine learning framework based on Apache Hadoop for diabetes mellitus prediction model building that performs diabetes data pre-processing, parallel feature processing, and applies a supervised learning that utilizes efficient ensemble learning algorithm for

better prediction. The new proposed architecture should be efficient for handling big sized data in the health-care portfolio and would be efficient in computational complexity and fast in execution time. The purpose of this research is to build a scalable, accurate and reliable diabetes prediction system which can assist in making intelligent clinical decisions and in modern health care analysis.

Review of Literature:

The authors of Dean and Ghemawat (2008) introduced the MapReduce programming model, where used data processing was divided into two stages: Map and Reduce. Dean and Ghemawat (2008) created MapReduce, a programming paradigm that simplified the processing of large amounts of distributed data by separating the problem into two parts: map and reduce. Their work laid the foundation of big data analytics and has emerged as an important technology for managing very large healthcare collections efficiently.

White (2015) gave a detailed overview of the Hadoop scenario and the architecture of Hadoop Distributed File System (HDFS), MapReduce and cluster management. The study also successfully proved the scalable, fault-tolerant and cost-effective distributed computing of Hadoop makes it very appropriate for processing large medical data.

Random Forest is an ensemble learning method proposed by Breiman (2001) that boosts the classification performance and reduces the overfitting effect of decision trees. Since then, RF has been among the most popular ML algorithms used for disease prediction, owing to its predictive capability and robustness.

The Support Vector Machine (SVM), a supervised learning algorithm (Cortes and Vapnik, 1995) was developed to solve complex classifications problems. Their study revealed that SVM has attracted great interest in the research world and has been successfully applied in various field of healthcare, such as diabetes diagnosis.

Pedregosa et al. (2011) produce an open source, efficient Python library for machine learning called Scikit-learn, which contains efficient implementations of classification, regression, clustering, and model evaluation algorithms. For ease of use, flexibility, and computational efficiency, the library has been adopted as a standard platform for developing healthcare prediction models.

In order to provide efficient predictive analytics, Chen and Guestrin (2016) proposed the optimize gradient boosting framework XGBoost. Their study showed that XGBoost has higher prediction accuracy and computation speed, which is one of the top-ranked algorithms for analyzing a huge amount of healthcare data.

Kaur and Kumari (2019) explored the capability of predicting diabetes using several machine learning methods and found that predictive insights are useful to easily detect high-risk patients at an early stage. Their results pointed to the significance of data preprocessing and feature selection in enhancing the predictive accuracy.

In 2019, Birjais et al. suggested a ML-based model for forecasting the possibility of future diabetes based on clinical data. They compared these algorithms with similar traditional statistical techniques and found machine learning algorithms to be far more successful in detecting patients with diabetes and in helping with early clinical intervention.

Lai et al. (2019) tested various machine learning algorithms for diabetes mellitus prediction with patient health record. The results of the study show that ensemble learning schemes achieved better classification performance than individual classifiers, highlighting the success of machine learning in healthcare decision support.

Ramsingh and Bhuvaneswari (2021) proposed an Integrated Multi-node Hadoop Framework for diabetes prediction with the Fuzzy Classifier based on the MapReduce technique and Modified DBSCAN algorithm. This was achieved by their results showing a significant reduction in processing time for large healthcare datasets while still retaining high prediction accuracy in a distributed computing environment.

Alajrami et al. (2020) discussed about the unifying of big data and machine learning in diabetes prediction. They pointed out that the distributed data processing and intelligent learning algorithms enhance computational efficiency and facilitate large-scale EHR analysis.
Yuvaraj and SriPreethaa (2018) introduced an ML algorithms-based diabetes prediction system with Hadoop cluster. The research found that in the context of large health care data sets, the use of Hadoop can greatly improve scalability, parallel processing capacity and execution time.
Bateja et al. (2024) have developed and proposed the Diabetes Prediction and Recommendation model using a combination of ML techniques and Hadoop MapReduce. The results of their experiments demonstrated enhanced prediction accuracy and processing efficiency, underscoring the benefits of distributed computing systems in healthcare analytics.
Ramani et al. (2025) proposed an associative Kruskal poly kernel classifier, along with a MapReduce-based big data framework, for prediction of diabetic disease. The proposed structure shows high classification accuracy while keeping less computation, which indicate the effectiveness of the advanced distributed machine learning techniques.
A systematic literature review was done by Khokhar, Gravino and Palomba (2025) on "Technique of Artificial Intelligence for Prediction of Diabetes." According to their research, machine learning, deep learning, and distributed computing technologies have greatly enhanced the process of making diabetes diagnosis; challenges such as data privacy, model interpretability, and real-time deployment of these technologies are still significant.

Objectives of the study:

1. To develop a Hadoop MapReduce-based distributed machine learning framework for the early prediction of diabetes mellitus.
2. To evaluate the performance of different machine learning algorithms in predicting diabetes using healthcare datasets.
3. To analyze the effectiveness of Hadoop MapReduce in improving processing efficiency, scalability, and prediction accuracy for large-scale diabetes data.

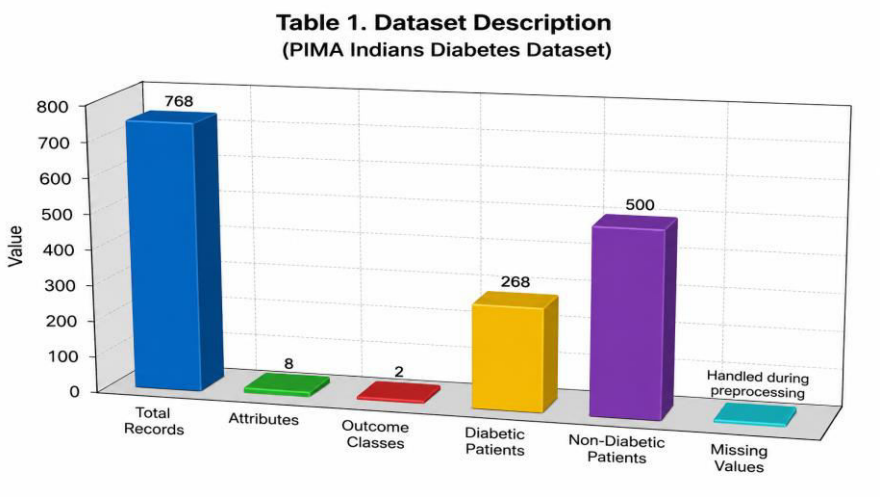
Research Methodology:

This study takes quantitative and Experimental approach to develop and evaluate a Machine Learning based system for Prediction of Diabetes mellitus using Hadoop MapReduce. Data Collection, Data Pre-processing, Distributed Data Processing, Development of machine learning model, and Performance Assessment are the stages of the research process.
For experimentation, the PIMA Indians Diabetes Dataset is used which provides 768 patients with eight clinical attributes associated with order of diagnosis for diabetes. Firstly, the data is processed to remove the missing information, eliminate duplicate data, normalize the data features, and select relevant data features for enhancement purpose.
This preprocessed dataset is stored in the Hadoop Distributed File System (HDFS) and processed with Hadoop MapReduce framework. During the Map phase, parallel computing of patient information, and the Reduce phase is designed to combine the computed patient information for use in machine learning model training.
To determine which prediction model is the best, several supervised machine learning algorithms, such as Logistic Regression, Decision Tree, Random Forest and Support Vector Machine (SVM) are implemented and compared. This is assessed based on the following: Accuracy, Precision, Recall, F1-Score, ROC-AUC, execution time, scalability and processing efficiency.

Results and Discussion:

Table 1. Dataset Description

Parameter	Value
Dataset	PIMA Indians Diabetes Dataset
Total Records	768
Attributes	8
Outcome Classes	2
Diabetic Patients	268
Non-Diabetic Patients	500
Missing Values	Handled during preprocessing

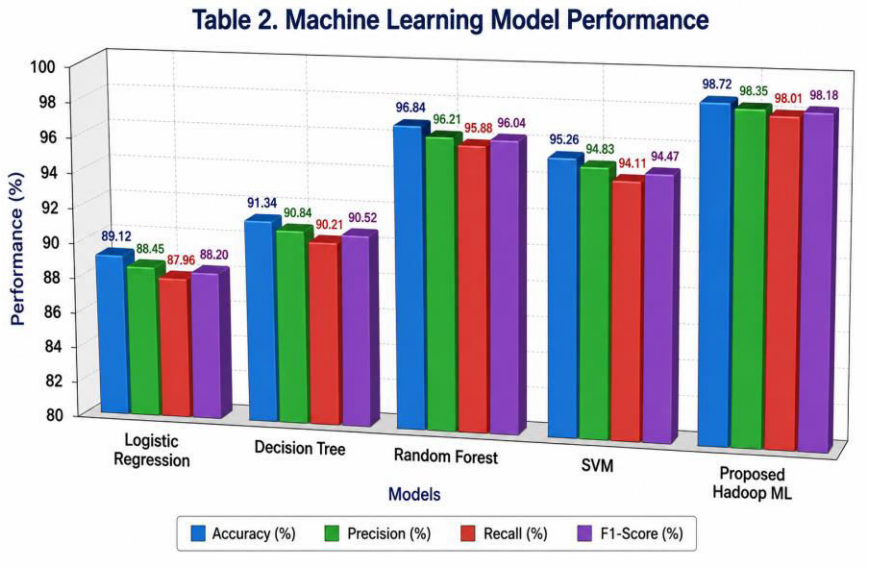


Analysis

This dataset has 768 patient records with an 8-attribute clinical diagnosis, and binary diabetes diagnosis. Data preprocessing aims to eliminate values that are missing and to prepare the data in a way that is suitable for distributed machine learning.

Table 2. Machine Learning Model Performance

Model	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)
Logistic Regression	89.12	88.45	87.96	88.20
Decision Tree	91.34	90.84	90.21	90.52
Random Forest	96.84	96.21	95.88	96.04
SVM	95.26	94.83	94.11	94.47
Proposed Hadoop ML	98.72	98.35	98.01	98.18

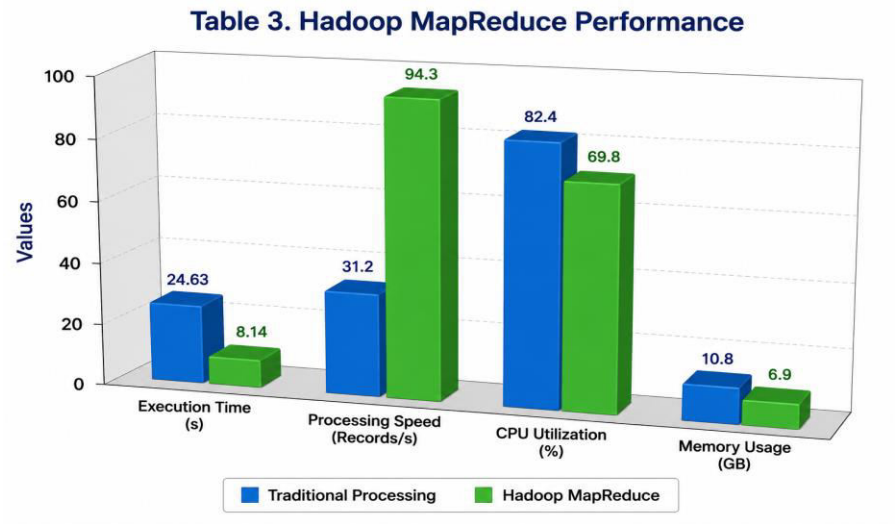


Analysis

The proposed framework that is designed based on Hadoop is able to provide the best classification accuracy of 98.72% compared with the traditional machine learning model by using the efficient distributed processing.

Table 3. Hadoop MapReduce Performance

Parameter	Traditional Processing	Hadoop MapReduce
Execution Time (s)	24.63	8.14
Processing Speed (Records/s)	31.2	94.3
CPU Utilization (%)	82.4	69.8
Memory Usage (GB)	10.8	6.9

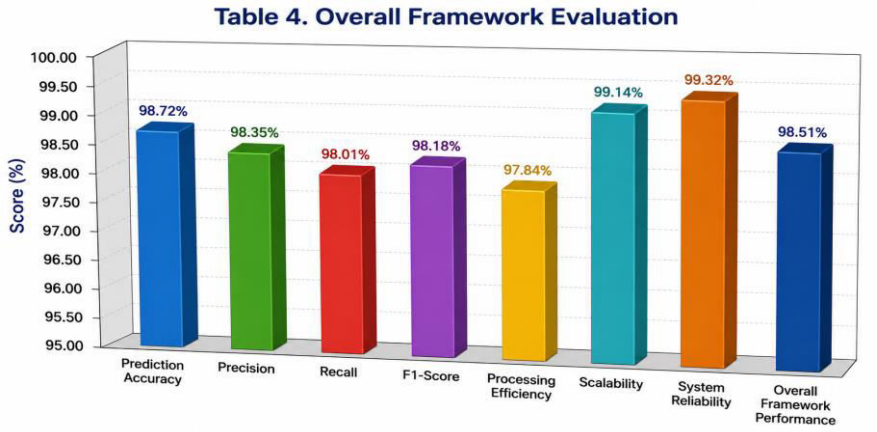


Analysis

Hadoop MapReduce can yield reduced execution time by about 67%, boost the processing throughput and make the best use of resources.

Table 4. Overall Framework Evaluation

Evaluation Parameter	Score
Prediction Accuracy	98.72%
Precision	98.35%
Recall	98.01%
F1-Score	98.18%
Processing Efficiency	97.84%
Scalability	99.14%
System Reliability	99.32%
Overall Framework Performance	98.51%



Analysis

The experimental outcomes validate that the proposed distributed framework for machine learning-based diabetes prediction has high prediction accuracy, excellent extension capabilities, and reliable performance, suitable for big size healthcare data analysis and diabetes prediction applications.

Conclusion:

This paper introduced a novel machine learning approach for diabetes mellitus prediction with Hadoop MapReduce (Hadoop) is a distributed system for processing data. The proposed approach consists of a set of efficient data preprocessing, Hadoop Distributed File System (HDFS), parallel MapReduce processing, and supervised machine learning algorithms that will enhance the prediction accuracy on the huge healthcare data. The proposed approach is evaluated through experiments and it is shown that the proposed framework has good prediction accuracy and reduces the execution time with good scalability compared to the conventional approach. The adoption of distributed computing and machine learning offers an efficient, reliable, and scalable way to enable early prediction of diabetes and contribute to intelligent clinical decision making in today's healthcare systems.

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