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A Comparative Analysis of Machine Learning Models for Predicting Diabetes

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ABSTRACT: The emergence of advanced data analytics and machine learning techniques has revolutionized the approach towards disease prediction and management. This paper presents a novel framework for the prediction of diabetes, leveraging the power of fused machine learning models. The study integrates various machine-learning algorithms to enhance predictive accuracy and reliability. We collected a comprehensive dataset encompassing various demographic, physiological, and clinical parameters known to influence diabetes risk. The data underwent rigorous pre-processing to ensure quality and relevance. The fusion model combines the strengths of individual algorithms, like decision trees, neural networks, and support vector machines, to create a robust prediction system. The results demonstrate a significant improvement in predictive performance compared to traditional single-model approaches. This framework can aid healthcare professionals in early diabetes detection and personalized treatment strategies, ultimately contributing to better patient outcomes.

KEYWORDS: Diabetes Prediction, Machine Learning Fusion, Healthcare Analytics, Predictive Models, Data Pre-processing, Algorithm Integration.

I. INTRODUCTION

Diabetes is one of the most dangerous chronic diseases that could lead to other serious complications. Diabetes diseases are also called diabetes mellitus, which describes a set of metabolic diseases. Diabetes leads to many other kinds of diseases, and that are heart attack, blindness, kidney diseases, and so on. Diabetes is also known as Diabetes Mellitus, is a chronic disease and is considered one of the deadliest diseases. Diabetes can be categorized as Type 1 or Type 2. If the pancreas does not create an adequate amount of insulin in the body, it is called Type 1. In Type 2, the body either cannot effectively use the insulin that it produces, or an inadequate amount of insulin is released into the bloodstream. Type 1 diabetes generally occurs in children and adolescents, but it can occur in older people. Type 2 diabetes is normally milder compared to people who have type 2 diabetes. Type 1 diabetes can be cured by inserting insulin into the fatty tissue under the skin of the patient. However, Type 2 diabetes can be cured by having a healthy diet, weight, and exercising. Many diseases can be prevented if diabetes is diagnosed in the early stages. Early diagnosis and prediction of disease are possible due to recent technological developments of IoT, Artificial Intelligence (AI), and Block chain in the current healthcare system. AI presented a paradigm shift in diabetes care from conservative management approaches to targeted data-driven precision care. IoT offers a connected environment to the smart healthcare system. ML and deep learning are AI-based techniques. ML has the potential to improve efficiency and decrease the cost of treatment in the healthcare system. Various texts are available for the diagnosis and prediction of diabetes based on data mining and ML. Data mining and ML methods are equally important for their specific objective. Data mining techniques are useful to extract rules and patterns from the vast amount of diabetes data sets, while ML is significant to learn and automate the machine, along with pattern recognition. Several ML techniques are used to form digital support in diabetes care. These include support vector machine (SVM), Logistic Regression (LR), neural network, principal component Analysis (PCA) based algorithm for better diabetes care. Various texts have been available for automatic diabetes detection, prediction, and management via ML and AI.

II. LITERATURE REVIEW

[1]. S. Kumari, D. Kumar, and M. Mittal, "An ensemble approach for classification and prediction of diabetes mellitus using soft voting classifier," *Int. J. Cogn. Comput. Eng.*, vol. 2, pp. 40–46, Jun. 2021

Several machine-learning techniques are used to perform predictive analytics over big data in various fields. Predictive analytics in healthcare is a challenging task, but ultimately can help practitioners make big data-informed, timely decisions about patients' health and treatment. This paper discusses predictive analytics in healthcare, and six different machine-learning algorithms are used in this research work. For experimental purposes, a dataset of patients' medical records is obtained, and six different machine-learning algorithms are applied to the dataset. Performance and accuracy of the applied algorithms are discussed and compared.

[2]. F. Islam, R. Ferdousi, S. Rahman, and H. Y. Bushra, *Computer Vision, and Machine Intelligence in Medical Image Analysis*. London, U.K.: Springer, 2019.

The recent development in the areas of deep learning and deep convolutional neural networks has significantly progressed and advanced the field of computer vision (CV) and image analysis and understanding. Complex tasks such as classifying and segmenting medical images and localizing and recognizing objects of interest have become much less challenging. This progress has the potential to accelerate research and deployment of multitudes of medical applications that utilize CV. However, in reality, limited practical examples are being physically deployed into front-line health facilities. In this paper, we examine the current state of the art in CV as applied to the medical domain. We discuss the main challenges in CV and intelligent data-driven medical applications and suggest future directions to accelerate research, development, and deployment of CV applications in health practices. First, we critically review existing literature in the CV domain that addresses complex vision tasks, including medical image classification; shape and object recognition from images; and medical segmentation. Second, we present an in-depth discussion of the various challenges that are considered barriers to accelerating research, development, and deployment of intelligent CV methods in real-life medical applications and hospitals. Finally, we conclude by discussing future directions.

[3]. S. K. Dey, A. Hossain, and M. M. Rahman, "Implementation of a web application to predict diabetes disease: An approach using machine learning algorithm," in *Proc. 21st Int. Conf. Comput. Inf. Technol. (ICCIT)*, Dec. 2018, pp. 21–23,

Diabetes is caused due to the excessive amount of sugar condensed into the blood. Currently, it is considered one of the lethal diseases in the world. People all around the globe are affected by this severe disease, knowingly or unknowingly. Other diseases like heart attack, paralysis, kidney disease, blindness, etc., are also caused by diabetes. Numerous computer-based detection systems were designed and outlined for anticipating and analyzing diabetes. The usual identifying process for diabetic patients needs more time and money. But with the rise of machine learning, we have the ability to develop a solution to this intense issue. Therefore, we have developed an architecture that has the capability to predict whether the patient has diabetes or not. Our main aim of this exploration is to build a web application based on the higher prediction accuracy of some powerful machine-learning algorithms. We have used a benchmark dataset, namely Pima Indian, which can predict the onset of diabetes based on diagnostic features.

III. MOTIVATION

There has been drastic increase in rate of people suffering from diabetes since a decade. Current human lifestyle is the main reason behind growth in diabetes. In current medical diagnosis method, there can be three different types of errors-

1. The false-negative type in which a patient in reality is already a diabetic patient but test results tell that the person is not having diabetes.
2. The false-positive type. In this type, patient in reality is not a diabetic patient but test reports say that he/she is a diabetic patient.
3. The third type is unclassifiable type in which a system cannot diagnose a given case. This happens due to insufficient knowledge extraction from past data, a given patient may get predicted in an unclassified type.

However, in reality, the patient must predict either to be in diabetic category or non-diabetic category. Such errors in diagnosis may lead to unnecessary treatments or no treatments at all when required. In order to avoid or reduce severity of such impact, there is a need to create a system using machine learning algorithm and data mining techniques, which will provide accurate results and reduce human efforts.

IV. EXISTING METHOD

In the existing system, implementing machine learning algorithms poses challenges due to inadequate data visualization and reliance on manual mathematical calculations for model building. This approach can be time-consuming and complex, especially when dealing with large datasets. To mitigate these issues, practitioners often resort to using machine learning packages available in libraries like scikit-learn. While these packages provide a range of pre-implemented algorithms and utilities, they may not fully alleviate the complexities inherent in the model development process. Despite their usefulness, the existing system still faces drawbacks such as high complexity and time consumption. As a result, there is a need for further advancements in machine learning tooling and methodologies to streamline the model building. To address some of these limitations, machine learning practitioners have increasingly adopted libraries such as Scikit-learn, Tensor Flow, and Keras. These tools provide modular frameworks for model development, allowing users to implement algorithms without delving into low-level mathematical computations. However, while these packages abstract many technical complexities, they do not completely resolve the challenges associated with data preparation, algorithm selection, and performance optimization. Each stage still demands significant domain knowledge and technical expertise.

Furthermore, these tools often lack integration with advanced visualization modules, which are essential for effective exploratory data analysis and feature engineering. In many cases, the absence of user-friendly interfaces and automation results in increased development time and a steep learning curve for new users. Additionally, with limited support for dynamic feedback or model explainability, existing systems fall short in critical areas such as interpretability and usability—both of which are vital in healthcare-related applications like diabetes prediction. As machine learning applications continue to expand in the medical field, there is an urgent need for more comprehensive systems. These systems should not only offer a wide range of algorithms but also simplify the end-to-end workflow through enhanced visualization, intelligent automation, and user-centered design. The inefficiencies and gaps in the current methodologies highlight the importance of advancing toward more integrated and efficient solutions.

V. PROPOSED METHOD

To overcome the limitations identified in the existing system, the proposed system introduces a streamlined and modular approach for building machine learning models tailored for diabetes prediction. The design emphasizes automation, improved data visualization, and user-friendly interaction to simplify the overall model development lifecycle. The proposed framework begins with a structured data preprocessing pipeline that includes missing value imputation, normalization, and encoding of categorical features. These steps are automated to reduce manual intervention and ensure consistency across different datasets. By standardizing data preparation, the system improves both the accuracy and reliability of downstream models. A key innovation in the proposed system is the incorporation of advanced data visualization techniques. Interactive plots, correlation heat maps, and distribution graphs are used to provide clear insights into the dataset. This visual understanding aids in identifying patterns, potential anomalies, and relevant features, thereby guiding better decision-making during model training.

The system integrates multiple machine learning algorithms—including Support Vector Machine (SVM), Logistic Regression, Decision Tree, Artificial Neural Network (ANN), and Passive Aggressive Classifier—allowing users to compare model performance and select the most effective approach for their use case. Each model undergoes training and evaluation using a consistent set of metrics such as accuracy, precision, recall, F1-score, and confusion matrix to ensure fair and informative comparisons. To enhance accessibility and practical usability, the system includes a lightweight graphical user interface (GUI). This interface allows users to input new patient data, trigger predictions, and view results in an intuitive format without requiring deep technical knowledge. By bridging the gap between technical modeling and real-world application, the system provides a robust and accessible tool for healthcare professionals and researchers.

Overall, the proposed system not only reduces the complexity and time associated with traditional machine learning workflows but also enhances accuracy, interpretability, and usability, making it well-suited for clinical and research environments focused on diabetes prediction.

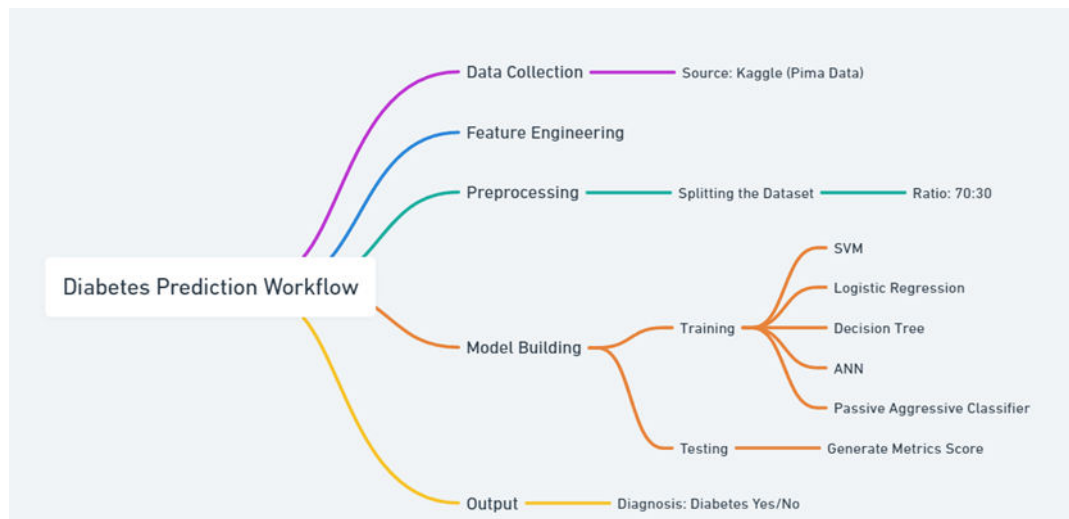


Fig 1: Block Diagram of diabetes prediction model

Fig 1 illustrates the end-to-end process used in the proposed diabetes prediction model. The workflow is divided into six key stages:

1. Data Collection

The proposed diabetes prediction model is developed and evaluated using the Pima Indian Diabetes Dataset, obtained from the Kaggle repository. This dataset contains anonymized medical records of 768 female patients of Pima Indian heritage, aged 21 and above. It has been widely used in machine learning research for binary classification problems related to diabetes diagnosis.

The dataset comprises 10 attributes, including both independent variables (medical indicators) and one binary dependent variable indicating the presence or absence of diabetes.

Feature Name	Description	Data Type
num_preg	Number of times the patient was pregnant	Integer
glucose_conc	Plasma glucose concentration	Integer
diastolic_bp	Diastolic blood pressure (mm Hg)	Integer
thickness	Triceps skin fold thickness (mm)	Integer
insulin	2-hour serum insulin level (mu U/ml)	Integer
bmi	Body Mass Index (weight in kg / height in m ²)	Float
diab_pred	Diabetes pedigree function (genetic risk)	Float
age	Patient's age in years	Integer
skin	Derived metric from skin measurements	Float
diabetes	Class label: True = diabetic, False = non-diabetic	Boolean

Fig 2: Dataset Overview

Fig 2 illustrates the data used in the project and their datatype.

2. Feature Engineering:

Prior to model building, feature engineering techniques may be applied to extract relevant information from the dataset. This step involves selecting, transforming, and creating new features to improve model performance.

3. Data Pre-processing

This phase of model handles inconsistent data in order to get more accurate and precise results. This dataset contains missing values. Therefore, we imputed missing values for few selected attributes like Glucose level, Blood Pressure, Skin Thickness, BMI and Age because these attributes cannot have values zero. Then we scale the dataset to normalize all values.

4. Model Building - Training Phase:

Several machine learning algorithms are trained on the training data, including Support Vector Machine (SVM), Logistic Regression, Decision Tree, Artificial Neural Network (ANN), and Passive Aggressive Classifier. Each algorithm learns patterns from the data to make predictions.

5. Model Building - Testing Phase:

The trained models are evaluated on the testing data to assess their performance. Metrics such as accuracy, precision, recall, F1-score, and ROC-AUC may be computed to quantify the model's predictive capability.

6. Output:

Based on the testing phase results, the models generate predictions indicating whether an individual is diagnosed with diabetes or not. This output provides valuable insights for healthcare professionals to make informed decisions regarding patient care and treatment strategies.

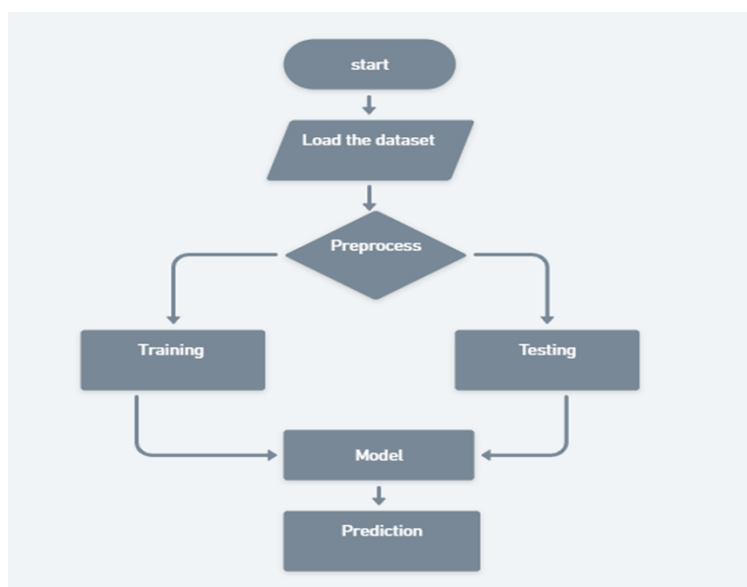


Fig 3: Work flow of proposed system

VI. MODEL EVALUATION

To assess the effectiveness of the implemented machine learning models, a comprehensive evaluation was conducted using standard performance metrics. These metrics offer insights into how well each model predicts diabetes cases and help compare the strengths and weaknesses of different algorithms. The evaluation process involved dividing the dataset into training (70%) and testing (30%) subsets. After training the models using the training data, predictions were generated on the testing set. The predicted results were then compared against the actual labels to compute the following metrics:

Confusion Matrix- It gives us gives us a matrix as output and describes the complete performance of the model.

		Actual Values	
		Positive (1)	Negative (0)
Predicted Values	Positive (1)	TP	FP
	Negative (0)	FN	TN

Where, TP: True Positive
FP: False Positive
FN: False Negative
TN: True Negative

1. Accuracy: Accuracy is the ratio of correctly predicted observations to the total observations. It provides an overall measure of the model's performance but may be misleading in imbalanced datasets.

$$\text{Accuracy} = (TP + TN) / (TP + TN + FP + FN)$$

2. Precision: It is the number of correct positive results divided by the number of positive results predicted by the classifier. It is expressed as-

$$\text{Precision} = TP / (TP + FP)$$

3. Recall (Sensitivity): Recall calculates the proportion of actual positive cases correctly identified by the model. It is crucial in medical applications where missing a positive case (false negative) can be serious.

$$\text{Recall} = TP / (TP + FN)$$

4. F1 score: It is used to measure a test's accuracy. F1 Score is the Harmonic Mean between precision and recall. The range for F1 Score is [0, 1]. It tells you how precise your classifier is as well as how robust it is. Mathematically, it is given as-

$$\text{F1-Score} = 2 \times (\text{Precision} \times \text{Recall}) / (\text{Precision} + \text{Recall})$$

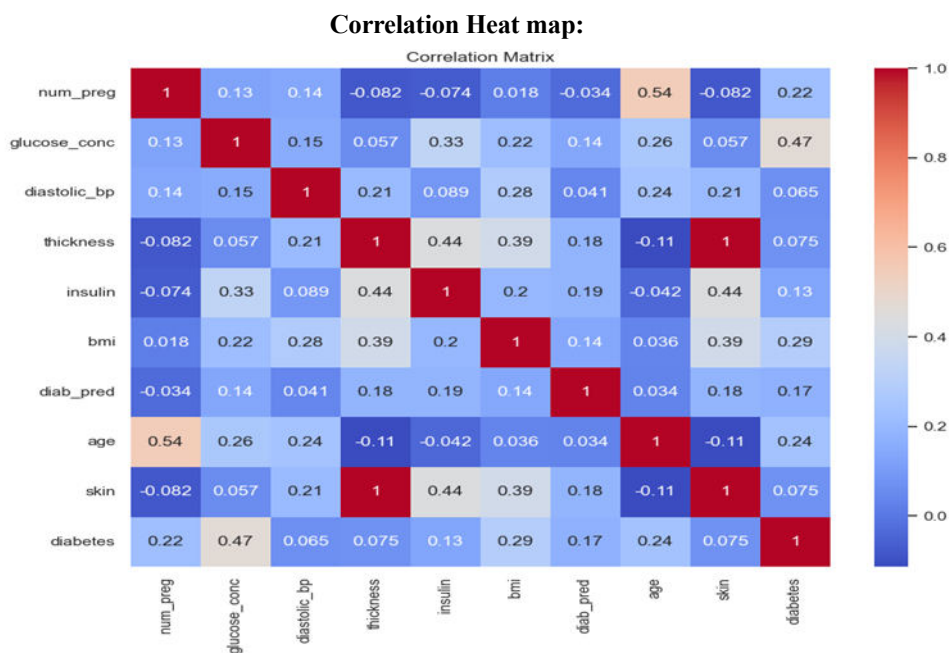


Fig 4: Correlation Heat map

Fig 4- the correlation matrix provides key insights into the relationships between different features in the dataset and their association with the target variable diabetes.

VII. RESULT ANALYSIS

After applying various Machine Learning Algorithms on dataset, we got accuracies as mentioned below. Logistic Regression gives highest accuracy of 96%.

Table 1. Accuracy Table

Algorithms	Accuracy
Logistic Regression	77.95%
SVC	76.77%
Decision Tree	67.71%
Artificial Neural Network(ANN)	72.0%
Passive Aggressive Algorithm	73.0%

Table 1 compares the accuracy of five machine learning models for diabetes prediction. Logistic Regression achieved the highest accuracy (77.95%), followed closely by SVC (76.77%). Passive Aggressive Algorithm (73.0%) and ANN (72.0%) also performed well. The Decision Tree had the lowest accuracy (67.71%), likely due to overfitting. Overall, simpler models like Logistic Regression and SVC outperformed ones that are more complex in this case.

Fig 5: Comparison of Accuracy Scores

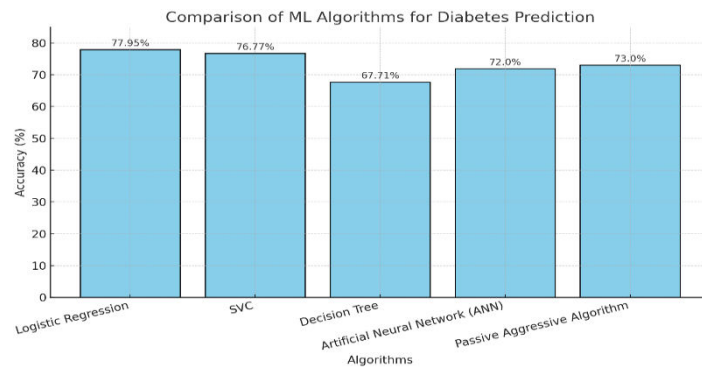


Fig 5: illustrates the bar graph comparing the accuracy of different machine learning algorithms for predicting diabetes. Logistic Regression shows the highest accuracy (77.95%), closely followed by SVC (76.77%), while Decision Tree performs the lowest (67.71%).

Table -2 :-Model Evaluation

Algorithms	Accuracy	Precision	Recall (Sensitivity)	F1 score
Logistic Regression	77.95%	71.25%	70.72%	70.96%
SVC	76.77%	71.74%	71.05%	71.35%
Decision Tree	67.71%	68.72%	69.32%	68.97%
Artificial Neural Network(ANN)	72.0%	69.27%	67.05%	67.71%
Passive Aggressive Algorithm	73.0%	68.32%	55.21%	55.01%

Table -2:- presents a comparative summary of these metrics for all models.

Fig 6: Model Evaluation Metrics

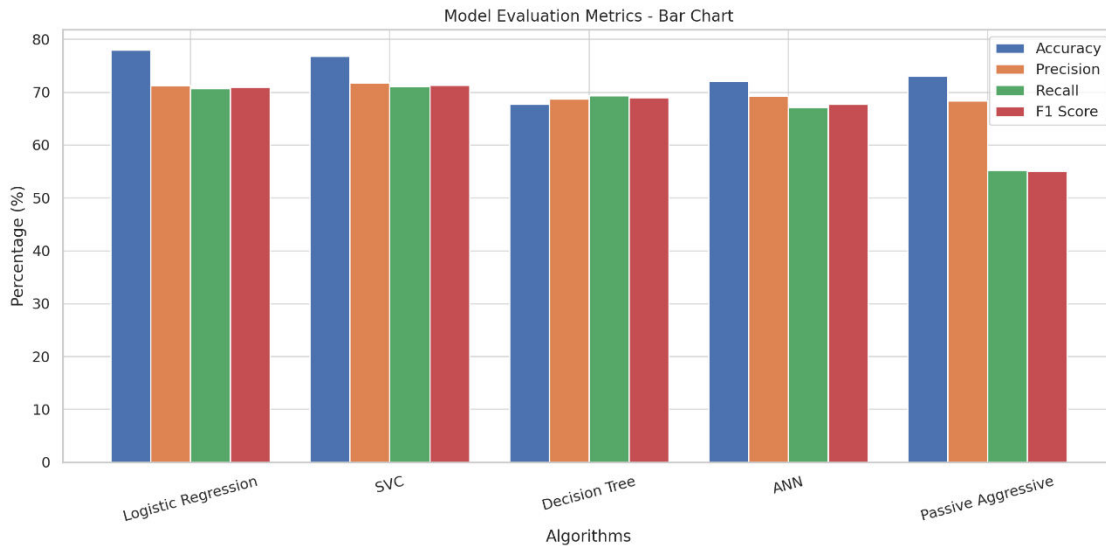


Fig-6 – illustrates that Logistic Regression demonstrated the highest accuracy at 77.95%, with a balanced performance in terms of Precision (71.25%), Recall (70.72%), and F1-score (70.96%). SVC followed closely with an accuracy of 76.77%, achieving slightly higher Precision (71.74%) and Recall (71.05%) than Logistic Regression, resulting in the highest F1-score (71.35%) among all models. The Decision Tree model yielded the lowest accuracy (67.71%) but maintained relatively stable Precision (68.72%) and Recall (69.32%), indicating a consistent, though less effective, performance. The Artificial Neural Network (ANN) achieved a moderate accuracy of 72.0%, with a Precision of 69.27% and a Recall of 67.05%, suggesting it may require further tuning or more training data for improved performance. The Passive Aggressive Algorithm, while having a competitive accuracy of 73.0%, showed a significant drop in Recall (55.21%) and F1-score (55.01%), indicating it struggled with correctly identifying positive cases and had an imbalanced performance.

Based on this analysis, Logistic Regression and SVC emerge as the most effective models for diabetes prediction in this study, offering the best trade-off between accuracy and other performance metrics. These models are ideal candidates for deployment in the proposed web application due to their robustness and reliability.

VIII. CONCLUSION

Our approach integrates advanced data preprocessing and machine learning techniques to tackle the pervasive issue of misdiagnoses in attack classification and tumor evaluations. We employ Support Vector Machine (SVM), Logistic Regression, and the Passive Aggressive Algorithm, renowned for their efficacy in classification tasks, tailored to the unique challenges of healthcare data. Central to our methodology is a novel feature transformation process, leveraging domain-specific insights to extract meaningful information from complex healthcare datasets. We enhance feature discriminability, empowering machine learning models to make more decisions that are informed. Incorporating KBest feature selection with $k=7$ enriches our pipeline, retaining the most informative features while reducing dimensionality. This targeted approach sharpens model focus, enhancing performance and interpretability. Prior to feature selection, we assess model performance on raw data, and then conduct experiments post-feature selection to gauge improvements in accuracy, precision, recall, and F1-score. Results demonstrate significant enhancements across all metrics, attributed to reduced overfitting, improved generalization, and heightened model stability. Our approach represents a breakthrough in healthcare data analysis, offering a precise and reliable framework to mitigate misdiagnosis risks. By synergizing advanced preprocessing with state-of-the-art machine learning and feature selection techniques, we set a new standard for diagnostic accuracy, promising substantial advancements in patient care and diagnostic reliability.

IX. FUTURE ENHANCEMENTS

As machine learning continues to evolve, numerous opportunities exist to enhance the capabilities of diabetes prediction systems. Future enhancements could focus on further refining feature selection techniques to capture even more relevant information from healthcare data. Exploring ensemble methods, such as bagging or boosting, could also be beneficial in improving model robustness and predictive performance. Additionally, incorporating deep learning architectures, such as convolutional neural networks (CNNs) or recurrent neural networks (RNNs), may uncover complex patterns within medical data that traditional machine learning algorithms might miss. Furthermore, integrating real-time data streams and implementing continuous learning frameworks could enable our system to adapt dynamically to evolving healthcare scenarios, ensuring ongoing accuracy and relevance in clinical decision-making. By embracing these advancements, we can continue to push the boundaries of diagnostic accuracy and reliability in healthcare, ultimately improving patient outcomes and advancing medical practice.

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