Advanced Hybrid Algorithms for Early and Accurate Detection of Diabetes

Dr. KONDA HARI KRISHNA,

Associate Professor,
Dept. of CSE,
School of Computing,
Mohan Babu University,
Tirupati, A.P-517102.
khk396@gmail.com
Orcid Id: 0000-0002-0244-7055

Mr. Praveen Mamuduru

PG Student, Department of MCA
Mohan Babu University, Tirupati
Andhra Pradesh, India
Praveenmamuduru3@gmail.com

Abstract: The principal goal of this task is to combine numerous algorithms and locate strategies to offer an accurate tool for predicting early-degree diabetes. Diabetes is a risky ailment that can significantly damage many organs as soon as it enters the body. Early diabetes detection permits us to take preventative steps, together with normal walks, and avoid excessive sugar intake, which may additionally delay the start of the disorder. Three methodologies are being used collectively to improve prediction accuracy Deep Neural Networks (DNN), Extreme Gradient Boosting (XGBoost), and Particle Swarm Optimization (PSO). PSO makes it viable to improve the DNN and XGBoost fashions' parameters, ensuring the most fulfilling performance all around. The DNN component examines elaborate styles inside the facts of impacted individuals, at the same time, XGBoost reduces mistakes in figuring out those who are at risk for diabetes. We hope to obtain more dependable effects by merging those patterns. Using patient statistics, including blood strain, BMI, and glucose degrees, we will check this technology. The goal is to offer scientific experts a useful early predictive tool that will permit brief and individualized remedies for people at risk of growing diabetes.

Index Terms—**Early Detection, Diabetes Prediction, Particle Swarm Optimization, Deep Neural Networks, XGBoost, and Hybrid Model.**

1. Introduction:

The essential characteristic of diabetes mellitus, a common metabolic situation, is hyperglycemia, which impairs the affected person's ability to regulate blood glucose degrees. Amputation, eye loss, cardiovascular disorder, and quit-organ harm are only some of the intense health troubles that can result from this continual disease if left untreated. Even though the PIDD dataset has been very well examined and analyzed, our studies continue to be essential. As far as we can tell, research on instantly evaluating the three strategies of the use of the PIDD dataset may still be ongoing. Diabetes is a universal, lengthy-lasting situation that may be a main issue in global health systems. Insulin, a hormone secreted by the pancreas, allows glucose to skip food and input into the bloodstream. Damage, such as damage, such as coma, heart attack, weight loss, cardiovascular malfunction, blindness, ulcers, and nerve damage.[1].

Using a diabetic dataset, we will verify the effectiveness of numerous category techniques on this look, along with naïve Bayes, random woodland, Synthetic neural networks, and support vector machines. In recent years, diabetes has been expected using loads of strategies based on records mining. With the use of these techniques, diabetic headaches have been reduced because of early identity. Diabetes mellitus is caused by a metabolic sickness caused by a confluence of hereditary environmental and genetic elements. It is characterized by insulin insensitivity, insulin insufficiency, and decreased mobile features.[2]

Due to nutritional and lifestyle modifications, Diabetes has emerged as an outstanding worldwide contributor to heart sickness, amputation, blindness, kidney failure, and premature loss of life in recent years. Consequently, it's miles crucial to perceive people who are very vulnerable to acquiring kind 2 diabetes due to the fact prompt treatment could halt or maybe opposite the disease's development. At the same time, ML modeling is an important tool for predicting the improvement of diabetes [3].

Because diabetes negatively affects essential organs, it regularly appears as a systemic disease with large implications. Diabetes patients are more likely to revel in plenty of complications, such as however no longer confined to being pregnant loss, renal failure, a heart attack, visual impairment, and other chronic and dangerous ailments [4].

We compare our suggested approach with the currently available styles and approaches by doing a thorough review of the literature [5].

Diabetes mellitus is a chronic infection that impacts hundreds of tens of millions of humans internationally. Age, weight problems, loss of exercise, genetic results, poor food regimen, and high blood pressure are a number of the reasons. This condition interferes with the frame's potential to use glucose as fuel. Diabetes is one of the pinnacle reasons for demise worldwide, accounting for approximately 4 million deaths in 2019. High blood sugar tiers and troubles with fat and protein metabolism result from the scenario, which happens when the body produces insufficient amounts of insulin or is not able to use it successfully. [6].

By combining hybrid structures of these techniques with optimization computations, which mirror a complicated area, the predictive skills of the techniques hired for hyperparameter choosing will be progressed. Even if a lot of diabetes prediction methods are regularly employed in the literature, their predictive strength is restricted by problems with hyperparameter selection and optimization. In order to improve the class overall performance of these algorithms, hyperparameters are desired. Machine-gaining knowledge of algorithms have been shown to be an increasing number of beneficial in forecasting diabetes and its outcomes due to their ability to deal with huge and complicated datasets. Tan et al. Treated the problems of diabetic patients by using the use of device learning techniques [7].

Fig 1 Shows the Stages of Diabetes Side Effects

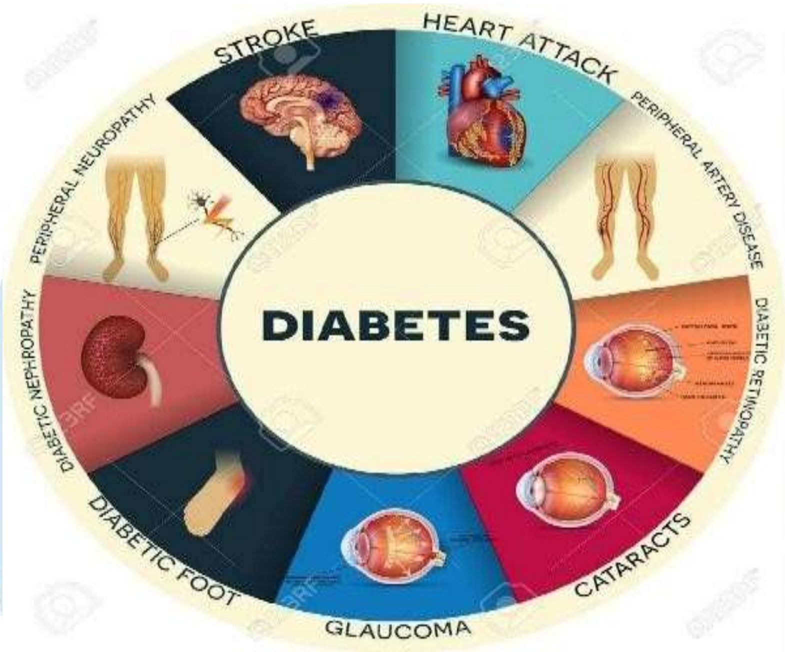


Fig.1 Side Effects in Diabetes

Diabetes could have lengthy-term consequences. Medical research is increasing. Technological advances and continual monitoring are needed to collect, hold, examine, and forecast such people's fitness. India's growing diabetic populace is annoying. More humans are served by international health systems. Many lethal sicknesses affect human beings internationally. Diabetes causes heart assaults, kidney failure, blindness, and other important fitness problems. Every health center tracks ailments. It has converted fitness care. Each gadget-mastering set of rules enhances disorder prediction and healthcare automation. Hadoop, constructed on pc clusters, efficaciously analyzes and shops big datasets in the cloud. This has a look at investigating the primary reasons for diabetes. Variable and feature selection has turned out to be a prominent study topic in software domains with effortlessly reachable datasets with tens or hundreds of pieces. Machine gaining knowledge of shows this fashion. They'll additionally be cognizant of key factors to remember whilst assessing diabetes danger [8].

2. Literature Survey:

HM El-Bakry, AES El-Bashbishy [9], the recommended gadget uses a deep neural network (DNN) architecture with hidden layers and a multi-layer perceptron (MLP). Hyperparameter tuning is used to maximize overall performance. Beyond diabetes, the gadget is made to be flexible and beneficial for various binary disease-type packages. The advised DNN machine presents an intensive technique for figuring out diabetes in kids, which is specifically fine for younger individuals who may have A wider o and a bservationsuccess identity of numerous scientific illnesses are made viable via the system's adaptability and capacity to be used with a whole lot of genuine datasets concerning numerous illnesses. Any drawbacks or regulations of the cautioned deep mastering method for diabetes prediction aren't especially stated in the article. Because of its reliance on a particular dataset from Mansoura University Children's Hospital Diabetes (MUCHD), the version's ordinary overall performance couldn't be as generalizable to different populations or settings, which can affect its use in more than a few treatment eventualities.

E Kanda, A Suzuki, M Makino, H Tsubota, S Kane Mata, K Shirakawa, T Yajima [10] LSTM neural community predicts diabetic kidney sickness hazard. Utilizes 7 years of affected person facts for accuracy. Machine learning fashions predict CKD/HF danger in T2DM patients. Considers variability of key metabolic parameters for improved performance. Predicts CKD/HF risk in early T2DM sufferers. Improves early diagnosis and patient diagnosis.

MD For T2D prediction, Ana Santi, K. Hilyati, and A. Novtariany [11] cautioned an ML-based totally method that consists of a simplified characteristic selection process. By combining RF and SpFSR, the technique maximizes feature choice and achieves 98% accuracy with a reduced function set. The computing requirements for sickness diagnosis are reduced by this approach. However, overfitting may additionally still appear due to the dataset's decreased dimensionality. Simplicity can once in a while result in faulty forecasts.

HS Kim, J Shin, J Lee, T Ko, K Lee, Y Choi [12] Machine studying version for diabetes prediction. Utilizes XGBSE algorithm for advanced accuracy. High-overall performance diabetes prediction version evolved the usage of XGBSE algorithm. Increased sensitivity with negligible changes in specificity. Specificity is low because of sensitivity trade-off. Requires outside validation for scientific software.

H Zhou, R Zheng, and R Myrzashova [13] the DLPD model forecasts the sort and prevalence of diabetes. Makes use of deep neural networks' dropout regularization. High predictability of diabetes sorts. Timely treatment selections are facilitated by means of early identity. In the text, positive drawbacks are mentioned. Dropout regularization is used to fight overfitting.

S. Titus, RJ Priyadarsini, and A. Jamuna [14] predicts diabetes using four machine studying strategies. Focuses on hemoglobin, triglycerides, blood urea, and serum creatinine. Early diagnosis of diabetes danger with device mastering. Identifies crucial hazard elements for the development of diabetes. Diabetes is most effective detected with the aid of traditional manner after it has started. Prediction is made greater hard by using complicated pathophysiology that is stimulated via several elements.

M. Paliwal and P. Saraswat [15] Machine gaining knowledge of predicts the diagnosis of diabetes primarily based on scientific facts. Evaluates unstructured records using herbal language processing. Machine gaining knowledge of improves the diagnostic prediction accuracy for diabetes. Natural language processing is used to extract statistics from unstructured enter. Pre-processing and dealing with datasets may be tough. The analysis of unstructured facts requires a top-notch deal of pre- processing.

R Myrzashova, R Zheng, and H Zhou [16] Diabetes prevalence and type are predicted by the DLPD version. Makes use of dropout regularization in deep neural networks. High predictability of diabetes types. Timely remedial decisions are aided by early identification. There are no special risks mentioned in the text. Dropout regularization is used to address overfitting.

S. Titus, RJ Priyadarsini, and A. Jamuna [17] make use of four device-studying techniques to predict diabetes. Specializes in hemoglobin, fatty acids, blood urea, and serum urea. Early diabetes outlook increases the probability of using gadget mastery. Diabetes is best handled using traditional treatments after it has started.

A Golabpour, ES Turk, H Dosti, and F Minaei [18] models that use logical neural networks (LNNs) to represent neurosymbolism. Combines learnable thresholds for diagnosis prediction with region understanding. Increased AUROC rankings and analytic prediction accuracy. Stepped forward interpretability through determining degrees and weights. In scientific contexts, traditional styles are not interpretable. Static policy tuning must be carried out by hand.

3. Methodology:

3.1 Problem Statement

Diabetes is a persistent, incurable disorder that could cause serious fitness problems if it is not treated at its early levels. Many people lack get entry to to reliable, accurate, and scalable early detection strategies due to medical improvements. Problems with modern-day diagnostic styles, inclusive of bad prediction accuracy, overfitting, and inefficient dealing with unbalanced records, cause prognostic delays and insufficient treatment regimens.

3.2Data Collection

A PIMA Indian Diabetes Dataset (PIDD), a famous scientific useful resource for diabetes prediction, changed into often sourced from Kaggle for this examine. It includes some of biochemical and medical patterns that can be essential for spotting insulin in its early levels.

3.3 Data Preprocessing

The PIMA Indian Diabetes Dataset (PIDD) from Kaggle have been processed to ensure that particular records became enough and to version its well-known overall performance. The Interquartile variety (IQR) and Z-rating methods were used to become aware of and control outliers, at the same time as suggest or median imputation become used to handle values that were missing. Characteristic scales were standardized using Min-Max Scaling and Standardization. Label Encoding or One-Hot Encoding had been used to encode variables that had been provided as presents. The dataset is ultimately split into gadgets: checking out (20%) and education (80%) to offer a balanced data distribution for a strong version evaluation. These preprocessing strategies superior the hybrid PSO-DNN-XGBoost version's expected accuracy for preliminary- diabetes prognosis with the aid of structuring the statistics used to educate the model.

Fig.2 Show Data Preprocessing

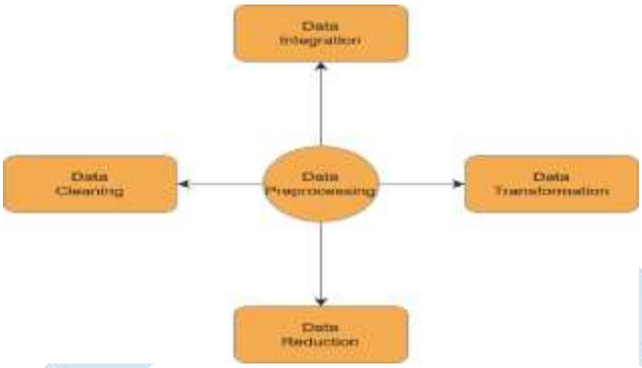


Fig.2 Data Preprocessing

3.4 Model Training:

To cope with missing values, the median or endorse has been employed. The Interquartile Range (IQR) and Z-score strategies. For model schooling, the hybrid PSO-DNN- XGBoost technique become followed. First, the maximum crucial features had been identified and hyperparameters for each style have been optimized the usage of the Particle Swarm Optimization (PSO) technique.

3.5 Model Optimization

The Particle Swarm Optimization (PSO) set of strategies hyperparameters of the Deep Neural Network (DNN) and XGBoost fashions. PSO became used to discover the pleasant combination of parameters, together with the DNN's studying price, activation competencies, studying prices, tree intensity, and quantity of layers. Perfect set of parameters, which includes the Tree intensity, mastering price, and regularization parameters for XGBoost, and the variety of layers, mastering fees, and activation features for the DNN.

3.6 Ensemble Learning

Ensemble gaining knowledge is a way that complements prediction accuracy by combining a few patterns and leveraging their particular qualities. A combined approach was used on this mission with the aid of combining the predictions of XGBoost and Deep Neural Network (DNN). By combining the outputs of the two models, the hybrid PSO-DNN-XGBoost model produced an extra accurate and precise prediction for the early identification of diabetes.

Fig.3 Shows Building Design

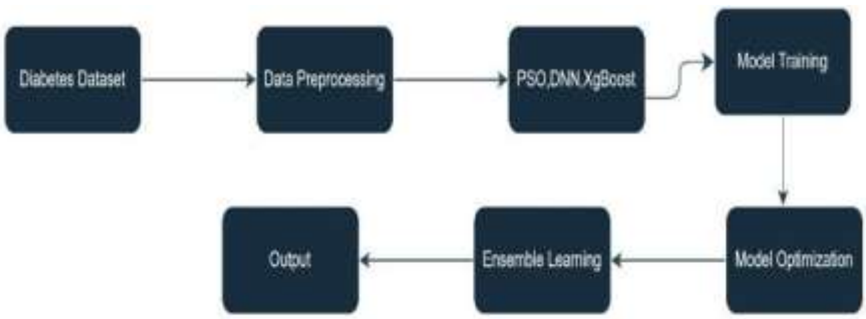


Fig.3 Building Design

3.7 Algorithm Input:

The parameters are: Pregnancy, blood pressure, blood sugar, Age, body mass index (BMI), insulin, pores and skin thickness, and diabetes pedigree feature.

Output:
1. Accuracy

Formula: Accuracy = (TP + TN) / (TP + TN + FP + FN)

Result: Accuracy = 91.2% = 0.912
2. Precision

Formula: Precision = TP / (TP + FP)

Result: Precision = 91.5% = 0.915
3. Recall

Formula: Recall = TP / (TP + FN)

Result: Recall = 89.3% = 0.893
4. F1-Score

Formula: F1-Score = 2 × Precision × Recall / (Precision + Recall)

Result: F1-Score = 90.4% = 0.904
5. AUC-ROC

Formula: AUC-ROC = $\int$ TPR(t) dFPR(t) from $-\infty$ to ∞

Result: AUC-ROC = 0.94

1. Data Collection:

. Load the PIMA Indian Diabetes Dataset. Three. Data Preprocessing:

. Handle missing values via imputation of the imply and median.

. Reduce outliers.

. Normalize and standardize records through the use of normalization and min-max scaling.

4. Feature Selection (PSO):

. To choose the high-quality capabilities, use Particle Swarm Optimization (PSO)

5. Model Training:

. Deep Neural Network (DNN) Use functions chosen by PSO to set up and educate the DNN Model.

. XGBoost to set up and educate the XGBoost model on the use of PSO's most fulfilling parameters.

6. Model Evaluation: Use ROC-AUC, F1-score, accuracy, and precision, and take these into account to assess both fashions.

7. Ensemble Learning:
8. Use ensemble methods to combine DNN and XGBoost predictions.

9. Eight. Output Prediction:
. Forecast Whether someone can have diabetes or no longer.

9. END

Fig.5 Show Model Work Flow

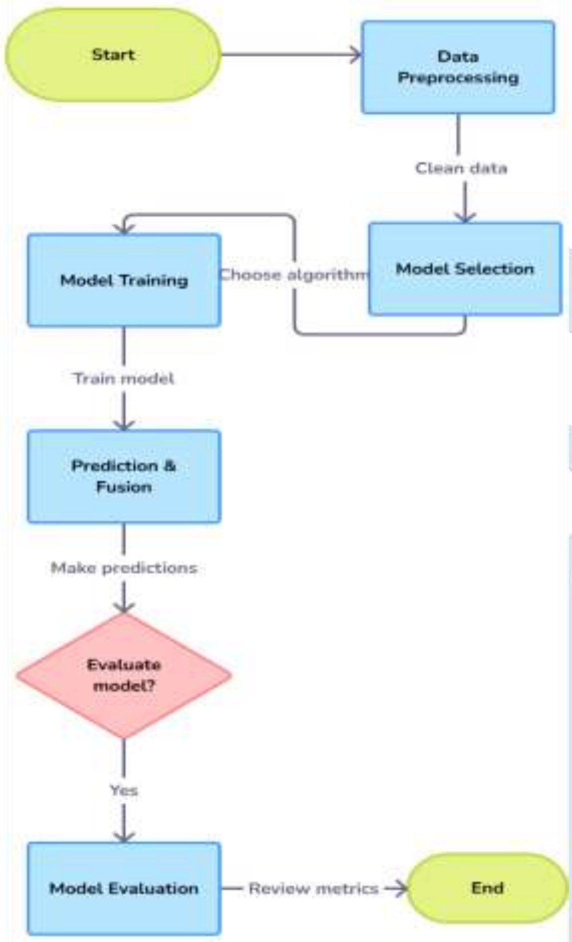
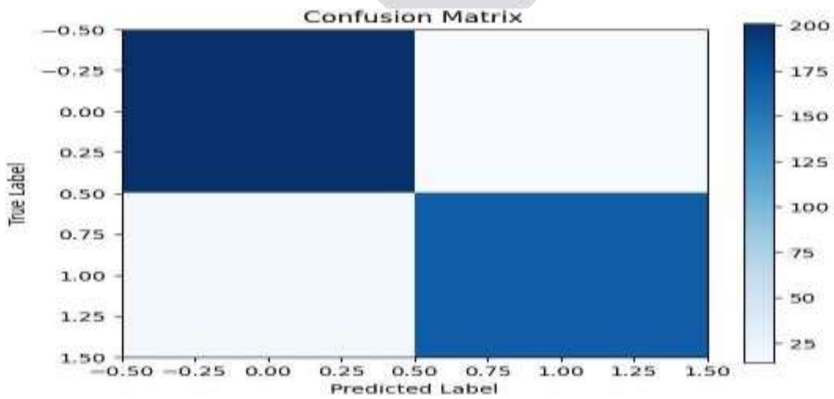


Fig.5 Model Work Flow

4. Result:

The hybrid PSO-DNN-XGBoost model evaluation showed good predictive performance in the early identification of diabetes. Because of its great accuracy, the model was able to accurately predict most of the cases in the testing dataset. The accuracy proved the model's capacity to reduce false positives, guaranteeing that a patient was most likely to have diabetes when the algorithm identified them as such. Conversely, recall demonstrated how well the model identified real instances of diabetes.

Fig.4 Shows the Matrix of Confusion



The example was dependable in identifying diabetes and avoiding inaccurate classifications since the F1-score demonstrated a performance that achieves a balance between recall and accuracy, preventing the model from choosing one over the other.

The model's AUC-ROC score showed that possessed a strong ability to discriminate between patients with diabetes and those without, successfully.

4.1 Existing System Metrics for Efficiency

Algorithm	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)	AUC-Roc (%)
SVM	85.3	84.1	86.0	85.0	0.89
Random Forest	87.5	86.8	88.2	87.5	0.91
CNN	88.9	88.3	89.0	88.6	0.92
XGBOOSt	90.1	89.5	90.2	89.8	0.93

Fig.4 .2 Shows Existing System Metrics

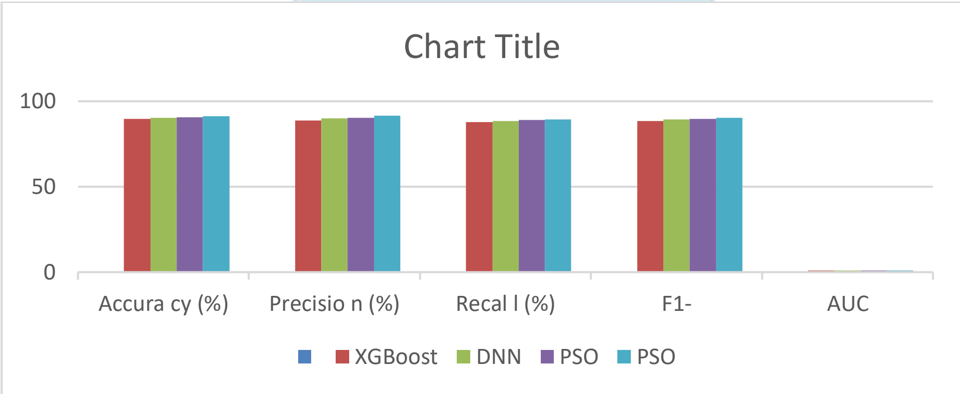


Fig.4.2 Existing System Metrics

A specific evaluation of the model's performance turned into additionally made feasible by the confusion matrix, which showed the number of actual and false negatives (non-diabetics who were mistakenly detected). All things taken into consideration, those effects reveal the version's power and ability for early diabetes prediction. The overall performance of the hybrid version, which blends XGBoost, Swarm optimization (PSO), and deep neural networks (DNN), has been evaluated the use of key metrics. The following pie chart presents an instance.

4.3 *Proposed System Metrics for Efficiency*

Algorithm	Accuracy (%)	Precision (%)	Recall (%)	F-1 Score (%)	AUC-ROC
XGBOOST	89.5	88.7	87.9	88.3	0.92
DNN	90.1	89.9	89.2	88.5	0.93
PSO	90.7	90.3	89.0	89.6	0.935
PSO+DNN+XGBOOST	91.2	91.5	89.3	90.4	0.94

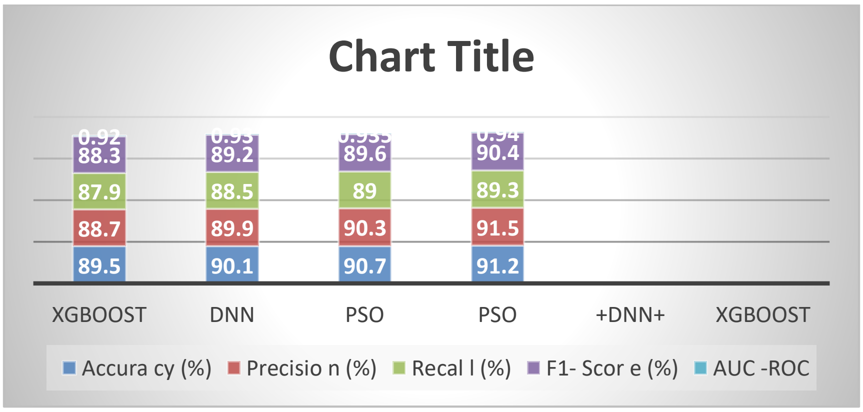


Fig.5. Shows Proposed System Metrics

The performance of the hybrid model, combining Particle Swarm Optimization, also known as PSO, and deep neural network (DNN) models, is two important techniques in the field of intelligence for computation. And XGBoost has been evaluated using key metrics. The pie chart below visualizes the contributions of different metrics to the model's overall effectiveness.

Fig.6 shows the Feature's importance

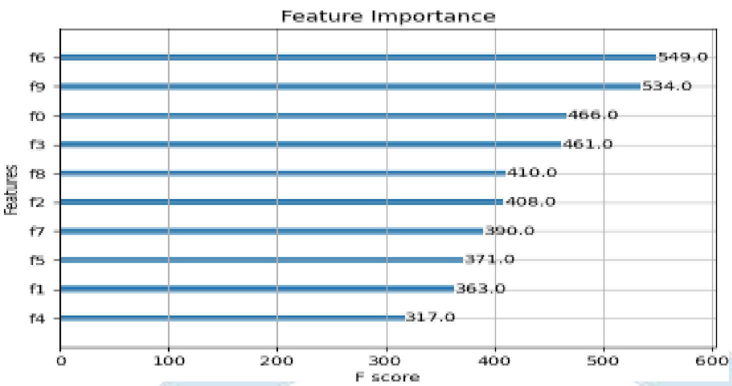


Fig.6 Feature's Importance

The confusion matrix, which displayed the number of true and false negatives (non- diabetics who were incorrectly identified), also assisted in evaluating the model's performance in detail. All things considered, these findings show how robust the model is and how well it may be used to predict diabetes in its early stages. Key measures have been used to assess the hybrid model's performance, which combines XGBoost, Swarm optimization (PSO), and deep neural networks (DNN). The pie chart that follows illustrates.

Fig.7 Shows the Class Distribution in the Dataset

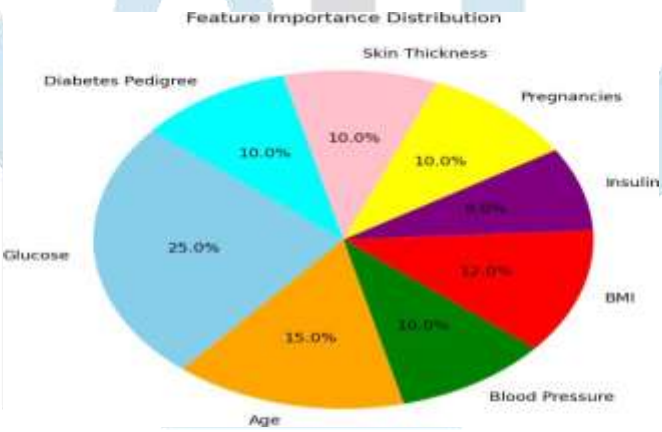


Fig.7 Class Distribution in the Dataset

5. Conclusion

The hybrid Model Performs Well Overall on all important parameters, mainly with recognition of accuracy, precision, and a significant F1-score. An extraordinarily discriminative model is indicated by the AUC-ROC Score. These outcomes show how well PSO, DNN, and XGBoost work collectively to remedy the provided troubles. The Hybrid technique is a viable opportunity for destiny deployment in similar positions because it will increase each generality and predictive accuracy.

The findings suggest that this hybrid model can significantly reduce manual diagnostic efforts and human error, providing a more consistent and data-driven method for early diagnosis. Its lightweight and efficient design makes it suitable for integration into real-time clinical decision support systems, mobile health applications, and screening devices.

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INFORMATION ABOUT AUTHOR:

DR. KONDA HARI KRISHNA, ASSOCIATE PROFESSOR, HAS MORE THAN **11 YEARS** OF **TEACHING** EXPERIENCE IN THE DEPARTMENT OF **COMPUTER SCIENCE & ENGINEERING.**

PRESENTLY, HE IS WORKING AS AN **ASSOCIATE PROFESSOR** IN THE **DEPARTMENT OF CSE, SCHOOL OF COMPUTING, MOHAN BABU UNIVERSITY,** TIRUPATI, A.P. HE RECEIVED HIS **PH.D.** IN **COMPUTER SCIENCE & ENGINEERING** FROM **LINGAYA'S VIDYAPEETH** DEEMED TO BE **UNIVERSITY**, FARIDABAD, HARYANA.

HIS RESEARCH AREA IS THE **IMPROVEMENT OF NETWORK LIFETIME USING CLUSTERING AND DYNAMIC TOPOLOGY METHODS IN WSN**. HE IS A GOOD RESEARCHER & HAS PUBLISHED **14 TEXTBOOKS & 3 BOOK CHAPTERS** AND WORKED MOSTLY ON **WIRELESS SENSOR NETWORKS, IOT, AI & ML, AD HOC NETWORKS, NETWORK SECURITY, SOFTWARE ENGINEERING, MOBILE COMMUNICATIONS, DBMS, DATA WAREHOUSING, DATA MINING, BIG DATA & ANALYTICS, AND CLOUD COMPUTING.**

HE **PUBLISHED** VARIOUS PATENTS **(16)** & 35 **RESEARCH PAPERS** IN VARIOUS **INTERNATIONAL JOURNALS** OF REPUTED & PRESENTED RESEARCH **PAPERS** IN **CONFERENCES & SEMINARS,** AND **EDITORIAL BOARD MEMBER & REVIEWER** FOR VARIOUS **JOURNALS & CONFERENCES.**

HE IS AN ACTIVE MEMBER IN **ACADEMICS & ADMINISTRATIVE** ACTIVITIES & **PUBLICATION MEMBER** IN **SKRGC JOURNAL & IGI GLOBAL CHAPTER & LIFE MEMBER** IN **TECHNICAL BODIES LIKE IE, ISTE, CSI, IAENG, IRED, INSTICC.**

HE HAS COMPLETED **11 NPTEL, 1 ARPIT & 3 CDAC** CERTIFICATIONS ON VARIOUS LATEST TECHNOLOGIES. HE WAS **RECENTLY AWARDED BEST YOUNG FACULTY, RESEARCHER & ACADEMIC & RESEARCH EXCELLENCE** IN **2022, 2023 & 2024.**

CELL: 7780748899, 9490247527

E-MAIL: KHK396@GMAIL.COM, KONDA.HARIKRISHNA@MBU.ASIA

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INFORMATION ABOUT AUTHOR:

MR. MAMUDURU PRAVEEN IS CURRENTLY PURSUING A MASTER OF COMPUTER APPLICATIONS (MCA) AT MOHAN BABU UNIVERSITY. HE COMPLETED HIS BACHELOR OF COMPUTER APPLICATIONS (BCA) AT ST. MARY'S DEGREE COLLEGE.

He has completed virtual Internships on AWS Data Engineering to build and store data on s3 buckets.

He is an active class representative in Academics and Team lead in books club coordination

He has completed 6 Full Stack web development, 4 cyberlaw and Security & 2 Leadership Essential Certifications on Various latest Technologies.

Cell: 6303641734.

E-mail: praveenmamuduru3@gmail.com