



IJRASET

International Journal For Research in
Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 7 Issue: V Month of publication: May 2019

DOI: <https://doi.org/10.22214/ijraset.2019.5313>

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Statistical and Machine Learning Methods for the Classification of Type -2 Diabetes Mellitus

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Abstract: *Diabetes mellitus is a chronic disorder of glucose metabolism either due to the relative deficiency of Insulin or due to the failure of body to respond to the action of insulin. Diseases leads to critical life threatening complications, if it remains undiagnosed and untreated. There is growing incidence of this disease all over the world. It has assumed epidemic form in Asian countries, China and India. Changing to urban life style, metabolic syndrome and obesity are some factors responsible for this increased prevalence. It is most common (90%) among the different types of diabetes.*

It is recognised by raised fasting or post prandial blood sugar level. The review of literature shows that one model does not always give good performance in all situations and data frames. The study aimed to address this issue of classification by the use of statistical and machine learning models. Present study is conducted on Pima Indian diabetic dataset which is publicly available and is widely used for diabetes research. Unlike other datasets, medical datasets usually suffer from missing and unwanted data which needs proper handling so that classification accuracy is significantly improved. Therefore, in this study mean, median, and linear regression based imputing techniques are developed and outliers are handled using winsorizing approach. Classification accuracy on imputed data are compared with the accuracy on raw data. Results on mean and median based imputed data significantly outperformed as compared against the raw data.

Keywords: *Type-2 Diabetes, Machine Learning, Imputing, Winsorizing*

I. INTRODUCTION

Diabetes is a chronic metabolic disease caused if the pancreas is not capable of producing enough insulin or body tissues become resistant to the action of Insulin. Most of the food we eat is converted into glucose by our body metabolism. Insulin helps in the proper utilization of glucose as a source of energy by our body cells. Hence deficiency or resistance to the action of insulin leads to increased levels of blood sugar (Hyperglycaemia). It causes major complications of heart, kidney failure, blindness, strokes etc. It has been reported that incidence of the disease has increased with time. According to WHO, number of adult diabetic patients has increased four times since 1980 to 2015. It caused 1.5 million deaths in 2012[7]. Diabetes will be a leading cause of death in 2030[2]

The disease has reached epidemic proportions in the world due to changes in the lifestyle of the people associated with westernization.[19]

Metabolic Syndrome characterized by large waist circumference, hypertriglycedaemia, elevated blood pressure and increased fasting blood sugar (more than 100mg/decilitre) has been recognized important for the prediction of diabetes and its complications. To reduce the burden of the disease, government should formulate new guidelines on the diabetic management. Public should be made aware of this fatal disease & its complications. Medicines and diagnostic services should be available to all sections of community.[20]

It becomes the responsibility of the clinicians to do proper screening and early detection of the disease. They should do frequent counselling of the patients and make them aware of therapeutic management of diabetes[21]. Progress in the technology in every field of basic and applied science has revolutionised computational world.

Applications of computational methods, more so during the last two decades has increased, due to advances in computer hardware and software technology. There is increased capacity of processing scalable, fixed and variable big data. This along with the advances in health and biosciences technology especially in high gene sequencing, has significantly increased the need for computational analysis[4].

Statistical and or machine learning approach is the latest trend in handling large medical applications. It is the intelligent data classification and prediction approaches which are contributing towards classifying, predicting and helping doctors with innovative strategies for patient care. Features of type-2 Diabetes treated as variables for statistical and machine learning analysis include fasting and post prandial blood glucose level, Body mass index, triceps skin fold, Blood pressure, age etc.

II. LITERATURE REVIEW

Han Wu, Shengqi Yang, Zhangqin Huang, Jian He, Xiaoyi Wang: They worked on PIMA Indian diabetic dataset. There is a great attention focused on the rising level of diabetics in high risk groups who are unaware of the diseases and its complications. Use of health records and other social data could help educating these groups. Prediction accuracy of the diabetes is enhanced by the computational methods using WEKA software. Benefits of this model are that it does not change or delete the original data and can be applied to other datasets besides PIMA Indian dataset. Limitations of this study are that it is time consuming. [1].

Nahla H. Barakat, Andrew P. Bradley and Mohamed Nabil H. Barakat:

In the context of diabetes we use Support Vector Machine computational model for the diagnosis of diabetes. Researchers have shown that the support vector machine provides a promising tool for the prediction of diabetes. A rule is generated with reasonable prediction accuracy using diabetic features as fasting blood glucose level and post prandial blood sugar level. This can be successfully used for prospective studies for diabetes prediction. [3]

Longfei Han, Senlin Luo, Jianmin Yu, Limin Pan, Songjing Chen:

Used SVM for rules extraction using Ensemble learning approach to screen the diabetes. Their model showed high quality diagnosis precision (98%). [5]

Bum Ju Lee and Jong yeol Kim:

The study of the association between the Waist circumference feature of human phenotype, blood triglycerides and the type-2 diabetes in adults is significant. The attributes taken into consideration are fasting blood glucose levels, Triglycerides levels and the physical measurements of the subjects. The evaluation is done by the use of logistic regression and naïve Bayes. With these prediction methods, it is found that there is strong association between the type-2 diabetes with waist circumference and triglyceride [6].

Exploring the reasons for developing diabetes mellitus various causal factors have been incriminated. These include diabetic pedigree, body mass index, waist circumference, central obesity & abdominal obesity. The life style and dietary changes due to environmental factors too have been blamed. The comparative study of different groups as Pima Indian ethnic group mothers and Indian origin students verifies this relationship with diabetes using statistical computation [8].

The quality and quantity of available data is very important for prediction and statistical analysis. This is more so for health record analyses. The missing values may be ignored if they are scattered in the data or may be replaced. Always there should be effort to collect maximum precise data. Various techniques are used to replace the missing values [9]. Hyan Kang discusses the importance of missing values and their handling. Efficiency of various statistical and classification models for diabetes show that results depend on the application. The complex data with more parameters may be suitable for one model and unsuitable for other. Feature and parameter selection needs experienced expert's help to increase efficacy [10]. Usually Weka software, which is available free, is used. Wenqian Chen et al. Some times a single model may not give as good performance as combination of two or more models, each model doing separate function one after other, for example first may be used for data correction followed by another for classification [11]. The professionals and scientists are working together to develop an automatic machine to diagnose a disease especially diabetes and its early prediction in non diabetics. The accuracy of these machine models varies. The study on Indian population shows satisfactory results [12]. It is observed that on going clinical trials and patients registered with health care organisations all over globe generate huge data which may be unstructured and even fixed data. To utilize this useful information for patient care management, one has to change from older methods to machine learning effective tool. [13]

Retinal vessel pathology in diabetes and hypertension are important preventable cause of blindness. Images of fundus taken with special cameras and then are distantly visualized by the ophthalmologists for early diagnosis. This branch of artificial intelligence namely deep learning is used to classify normal and retinal images. This needs further research to consolidate. [14]

Timothy S, Barley John Walsh and Jenine Y. Stone:

They discussed the data management, decision analysis and algorithms for Diabetic care. Algorithms for Insulin adjustments have been developed for the diabetic self management [15].

Valeriyalyssenko and Markku Laasko: The study of interaction between environment and genes is vigorously investigated. Some single gene modifications have been identified. Such genetic variants increased the risk of diabetes [16]. This needs to be researched further.

D. Kerr, C. Axelrod, C. Hoppe, D. C. Kioneff:

The present focus is on future technological innovations which will develop devices with sensors which communicate with computer and help in reducing the dependence on the professionals. Authors opinion is that by next decade, artificial intelligence and machine learning will largely be used to support diabetic care health management systems [17].

III. PROBLEM FORMULATION

Medical dataset are rarely clean and homogenous. Generally they are unbalanced, incomplete, and inconsistent. This could lead to wrong classification of the dataset for any given model being used. Thus, pre-processing is an important step to obtain meaningful data in order to improve the classification. The handling methods generally include filling missing values, outlier's detection, features ranking etc. In this paper, two way approach is presented to improve the classification :

A. Handling Missing Data

Three different methods are proposed to impute the missing values. They are:

- 1) *Simple mean based imputation:* In this approach first all missing data are removed from the dataset and then mean of the rest data is calculated and filled in place of missing data.
- 2) *Simple median based imputation:* Like simple mean based imputation, here also first all missing data have been removed and then median of the rest data is calculated and filled in place of missing data.
- 3) *Linear regression based imputation:* In this method first statistical significance ($P < 0.05$) of one attribute is checked with rest of the attributes using t-test and the attribute having maximum dependent attributes will be considered for linear regression. Suppose if BMI is statistically significant with Plasma glucose concentration, Diastolic blood pressure etc. then linear regression will be performed between BMI and Plasma glucose, and considering BMI as independent variable and Plasma glucose concentration as well as Diastolic blood pressure as dependent variable. Once, the equations are established then this equations will be used to fill the missing data.

B. Handling Outliers

After imputation with any of the above methods, winsorizing method with 2% winsorization window was used to remove the outliers from the dataset. Winsorizing is the transformation which limits the extreme range values in the data in order to reduce the effect of outliers. In statistics, the outliers are the data points whose spaces are significantly different from the rest of the data points.

Different machine learning models: used for evaluation are linear and. Logistic Regression . Linear Discriminant Analysis , K-Nearest means KNN Classification and Regression Tree . Naïve Bayes (NB) Support Vector Machine Random Forest Adaboost Classifier and . Quadratic Discriminant Analysis .The performance was assessed by these.

IV. RESULT AND DISCUSSION

A. Dataset

In this research Pima Indian diabetes data has been used. It is publicly available and widely used dataset for diabetes research and can be downloaded from University of California repository or some other sources like Kaggle etc. The data comprises of attributes , 768 instances and one binary class attribute. The data is the collection of health related information of Pima Indian women is of twenty years age and above.

The attributes/ features of the data are:

Number of times pregnancies , Plasma Glucose concentration, Diastolic Blood pressure

Triceps skin fold thickness , Two hour serum insulin (milli meu U/ml),

Diabetes pedigree function, Age in Years.

Class attributes for diabetes

0 for non diabetic

1 for diabetic

Table.1: Missing elements from raw dataset

S.N.	Features	Total Instance	Missing values	Missing values in %
1	Plasma glucose concentration	768	5	0.6
2	Diastolic blood pressure mm Hg	768	35	4.5
3	Triceps skin fold thickness (mm)	768	227	29.56
4	2-Hour serum insulin (mu U/ml)	768	371	48.31
5	Body mass index Kgm-2	768	9	1.2

It is observed that this dataset contains lots of missing data. Out of nine features, only 5 have missing elements as shown in Table 1. However, Two- hour serum insulin & triceps skin fold thickness have large number of missing elements.

B. Analysis of Missing data

C. Data distribution and correlation

The density plot gives a clear idea about the distribution of the data and correlation is used to find the correlation between two variables. Blue color shows the density plot of positive class while red color shows the density plot of negative class. More will be the difference in distributions between these two, better will be the classification. As shown in table 1 that Two hour serum insulin and t skin fold thickness have large number of missing elements, however it is maximally overlapped which makes classifier difficult to classify with the help of non-isolating samples. Therefore, the classifier poorly ranked these features. However these features are very important for the classification of diabetes. Distribution of the attributes and correlation among them are shown in Figure 1.

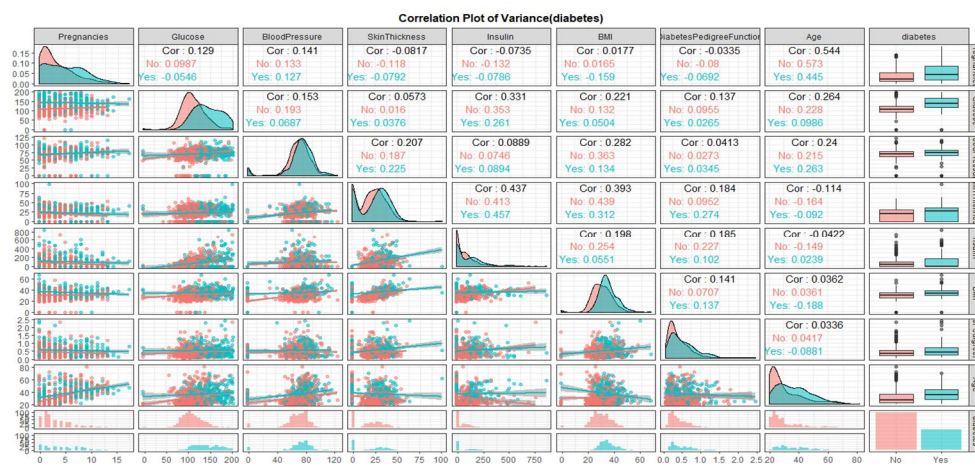


Figure 1: Distribution plot of raw data

V. RESULTS

Proposed approach is tested on Pima Indian Data and the results are compared with the results on raw data. Missing data are first imputed using three different techniques simple mean, simple median, and linear regression. BMI is found highly correlated with Plasma glucose concentration $P<0.001$ Diastolic blood pressure $P<0.001$ Triceps skin fold thickness $P<0.001$ and two hour serum insulin $P<0.001$, therefore linear regression is performed individually between BMI and all these factors and the equations obtained are used to fill the missing data. K-fold cross validation is performed on imputed data and the classification accuracy are shown in Table below. Imputing through simple mean and simple median improves the classification accuracy as compared against raw data. However, imputing through linear regression degrades the classification accuracy. The accuracy is further improved by removing outliers. After applying outlier removal technique, classification accuracy has been improved from maximum 83.88 % to 84.31 % on mean imputed data, while the accuracy has been improved from 84.22 % to 84.75 % on median imputed data.

Table 2: Accuracy results of raw dataset using machine learning methods

Classifier	Raw Data	After outliers removal
LR	77.99 (5.01)	77.60 (5.15)
LDA	77.35 (5.16)	77.22(5.09)
KNN	74.21 (7.15)	75.12(6.27)
CART	72.78 (7.69)	72.52(7.19)
NB	75.52 (4.28)	75.52(4.84)
SVM	77.34 (4.56)	77.21(4.16)
RF	75.90 (5.98)	76.43(6.68)
Ada boost	75.39 (4.60)	75.65(4.78)
QDA	73.69 (4.91)	74.35(5.79)

Table 3: Classification accuracy of imputed dataset using machine learning methods

Classifier	Simple Mean	After outliers removal	Simple Median	After outliers removal	Linear Regression with BMI	After outliers removal
LR	83.81 (4.22)	84.31 (4.24)	83.95 (4.25)	84.75 (4.32)	77.34 (4.76)	76.69 (5.06)
LDA	83.88 (4.42)	84.10 (4.29)	84.22 (4.30)	84.37 (4.36)	76.82 (5.02)	76.96 (4.93)
KNN	79.29 (4.36)	78.59 (4.56)	79.23 (4.29)	79.91 (4.95)	73.18 (4.15)	74.09 (4.69)
CART	77.61 (9.07)	78.52 (8.87)	77.75 (9.35)	78.26(9.01)	73.83 (7.21)	73.96 (7.05)
NB	82.19 (4.20)	82.97 (3.88)	81.75 (4.12)	82.87 (3.89)	75.52 (4.28)	75.52 (4.95)
SVM	83.72 (4.11)	83.76 (4.38)	83.78 (4.33)	83.97 (4.30)	76.95 (4.43)	76.95 (5.02)
RF	82.72 (5.49)	82.25 (5.44)	81.89 (6.75)	83.93 (5.14)	76.17 (5.60)	76.68 (6.11)
Ada boost	82.17 (4.26)	81.99 (3.65)	81.09 (4.21)	81.77 (3.72)	74.74 (6.18)	75.00 (5.14)
QDA	80.97 (4.23)	81.70 (4.16)	80.81 (3.98)	81.51 (3.82)	74.22 (3.97)	74.62 (4.47)

After imputation, we further analyzed the distribution plot of imputed data. After imputation through mean and median, a clear non-overlapping pattern has been observed in Two hour serum insulin and triceps skin fold thickness as shown in Figure 2. This pattern greatly improved the classification accuracy of the classifiers. On the other hand, the patterns using linear regression approach are almost same as the patterns of raw data, thus no improvement have been observed.

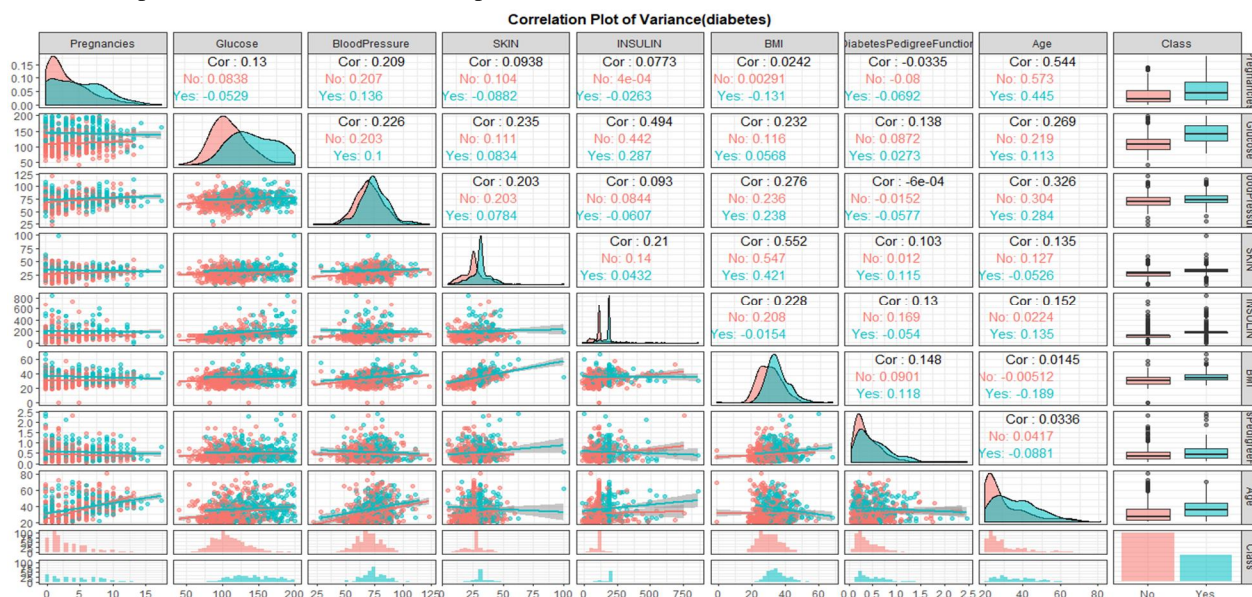


Fig 2: Density and Correlation plot of Variance with values

VI. CONCLUSION

In this research, machine learning based diabetes classification model is developed. On raw data, classification accuracy is maximum(77.99%) with Logistic Regression while the average classification accuracy is just 75.57 %. This classification accuracy is due to a large percentage of missing data in PIMA Indian Dataset. The proposed approach consisted of (i) imputation of missing data (ii) outliers detection and (iii) classification using machine learning methods. For imputation three different approaches were used (i) mean (ii) median and (iii) linear regression. Winsorizing approach is used for outliers detection in combination with 9 different machine learning classifiers. Imputing through simple mean and simple median improves the classification accuracy as compared against raw data. However, imputing through linear regression degrades the classification accuracy. The accuracy was further improved by removing outliers. After applying outlier’s removal technique, classification accuracy has been improved from maximum 83.88 % to 84.31 % on mean imputed data, while the accuracy has been improved from 84.22 % to 84.75 % on median imputed data. Hence, mean and median based imputation technique with winsorizing technique can be used to improve the classification accuracy.

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