Return on investment framework for profitable crop recommendation system by using optimized multilayer perceptron regressor

Surekha Janrao[1], Deven Shah[2]
[1]Department of Computer Engineering, Terna Engineering College, Navi Mumbai, India
[2]Department of Computer Engineering, Thakur College of Engineering and Technology, Mumbai, India

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ABSTRACT

Return on investment (ROI) plays very important role as a financial dimension in the agriculture sector. Many government agencies like Indian space research organization (ISRO), Indian council of agricultural research (ICAR), and Nitiayog are working on different agriculture projects to improve profitability and sustainability. This paper presents ROI framework to recommend more profitable crop to the farmers as per the current market price and demand which is missing in the existing crop recommendation system. Crop price prediction (CPP) and crop yield prediction (CYP) system are integrated in the ROI framework to predict more demandable crop to yield. This framework is designed by applying data analysis to provide regression statistics which further helps for model selection and improve the performance also. Optimized multilayer perceptron regressor algorithm has been evaluated through experimental results and it has been observed that it gives better performance as compared to other existing regression techniques.

Corresponding Author:

Surekha Janrao
Assistant Professor in Department of Computer Engineering, Terna Engineering College
Nerul, Navi Mumbai, India
Email: surekhajanrao@ternaengg.ac.in

1. INTRODUCTION

Agriculture is very bright sector in Indian economic growth. So, there is a need to do the research work in agriculture domain. As Indian population is increasing day by day so there is more requirement of crop yield. To increase the crop yield and profit for the farmers more accurate and profitable crop should be cultivated. This is achieved by considering financial dimension as a return on investment (ROI) which helps for the farmers to take more accurate and an intelligent decision for the crop selection based on the profit and loss as per the market price and demand [1]. Transition is very much required from traditional thinking to more advanced thinking. This can be achieved by providing accurate information on the tip of the finger to the farmer as a knowledge data discovery using modern technology like machine learning (ML), deep learning (DL), and internet of things (IoT) [2]. In this paper we are presenting the work on development of ROI framework by using more efficient machine leaning techniques which can improve the performance of the crop recommendation system. In this paper an emphasis given on the agricultural problems and prospectus of yeola taluka which is located in Nashik district of Maharashtra state. There is uneven distribution of rainfall in this study area. The socio-economic status of this area is primly bound to agriculture. In our research study we find the low productivity of land, scarcity of water, traditional methods of farming, uneven climatic changes, economically backwardness of farmers, fragmentation of farm and enormous low market prices for agricultural products. These are the basic problems of this region which motivates us to do the research work in such type of area which can increase economic growth of this farmers by providing more efficient crop recommendation system [3]. ROI framework is designed by integrating crop yield prediction (CYP) system and crop price prediction (CPP) system. This framework is developed by using data set collected from yeola region with the help of different government agencies. In this research work we have applied data analysis on collected data set to get regression statistics. We have implemented multiple regression model considering soil fertility index (SFI) as a most important feature and climatic factors as other attributes for CYP. And different levels of market price as min, max, avg for the CPP [4]. In this paper we have evaluated performance of different regression algorithms and results shown that improved sequential minimal optimization (ISMO) and multilayer perceptron (MLP) regression model gives better performance as compared to other machine learning algorithms for regression. Later MLP model will get optimized to get better results by applying hypertunning process on the existing one [5]. Much research worked on traditional machine learning algorithms as support vector machine (SVM), naïve Bayes (NB), random forest (RF), and decision tree (DT) for analyzing and predicting the crop based on soil and whether parameters, detailed description of this work is given in the reference [6], [7]. But the main disadvantage is that due to lack of optimization technique these algorithms are not giving better performance, and which is overcome in our current research work by applying hyper parameter tuning process for accurate model selection.

Some authors worked on different neural network algorithms, hybrid approach of different machine learning algorithm, boosting, and bagging techniques, adaptive clustering methods, association mining techniques for crop recommendation system. But in this research work financial dimension is missing i.e., ROI which is very important component which helps to improve economic growth of the farmers if accurate information is provided to them as well as other agriculture experts by using intelligent approach of modelling in the crop recommendation framework [8]–[10]. Some authors worked on ontology based farming and analysis of agriculture data using data mining techniques [11], [12]. In our research work we have developed ROI framework by integrating crop yield and CPP system to recommend more suitable crop to the farmers.

In the reference paper [13] research work has been done for crop recommendation system by using convolutional neural networks (CNN) which is the most widely used deep learning algorithm. But results show that no specific conclusion can be drawn as to what the best model is, but they clearly show that some machine learning models are used more than the others .We are integrating two different systems as CPP and CYP to get ROI framework and output is continuous real value. In the reference [14] researchers done an extensive experimental survey of regression methods by using all the regression datasets of the union cycliste internationale (UCI) machine learning repository. In this survey they have evaluated more than 77 regression models belonging to 19 different families like nearest neighbors, regression trees and rules, RF, bagging and boosting, neural networks, DL, and support vector regression.

In our experimental research work we observed that sequential minimal optimization (SMO) regressor (SMO algorithm for SVM regression) and MLP regression working more efficiently as compared to other regression techniques like bagging regressor, Gaussian regressor, RF regressor, AdaBoost regressor [15]. In this paper, researchers address the SVM regression problem and proposed an iterative algorithm, called SMO, for solving the regression problem using SVM. This algorithm is an extension of the SMO algorithm proposed by platt for SVM classifier design. They have suggested two modifications of the SMO algorithm that overcome the problem by efficiently maintaining and updating two threshold parameters. Their computational experiments show that these modifications speed up the SMO algorithm significantly in most situations.

In the reference [16] researchers worked on MLP-regressor for multiple linear regression analysis and artificial neural network (ANN) as tools for performance measurement has been employed in this work. In the reference [17] researchers concludes that with respect to the parametric model, the ANN has shown better results from the statistical analysis that it is a better modelling technique to support decision making for various type of recommendations. Nashik district is a major agriculturally dominant district in the Maharashtra. Therefore, it is important to highlight the less developed agricultural region and try to promote agricultural development. So, our present work is an attempt in the same direction but at taluka level we have selected as yeola regions. In topographical research study of Nashik district at tehsil level titled as “Spatial analysis of agricultural development in Nashik district: A Tahsil level study” [18]. This research study helps us to identify research challenges and understands topographical condition of yeola region so that we can move forward in proper direction.

2. RESEARCH METHOD FOR RETURN ON INVESTMENT (ROI) DIMENSION

ROI framework has been designed by using CYP system and CPP system. Performance analysis of various machine learning algorithms are evaluated to identify more efficient ML algorithm. This framework will predict accurate and profitable crop based on the profit and loss calculated by considering all type of expense cost from initial cropping to final harvesting. This framework recommends more profitable crop as final output by integrating CYP and CPP model as shown in the following Figure 1.

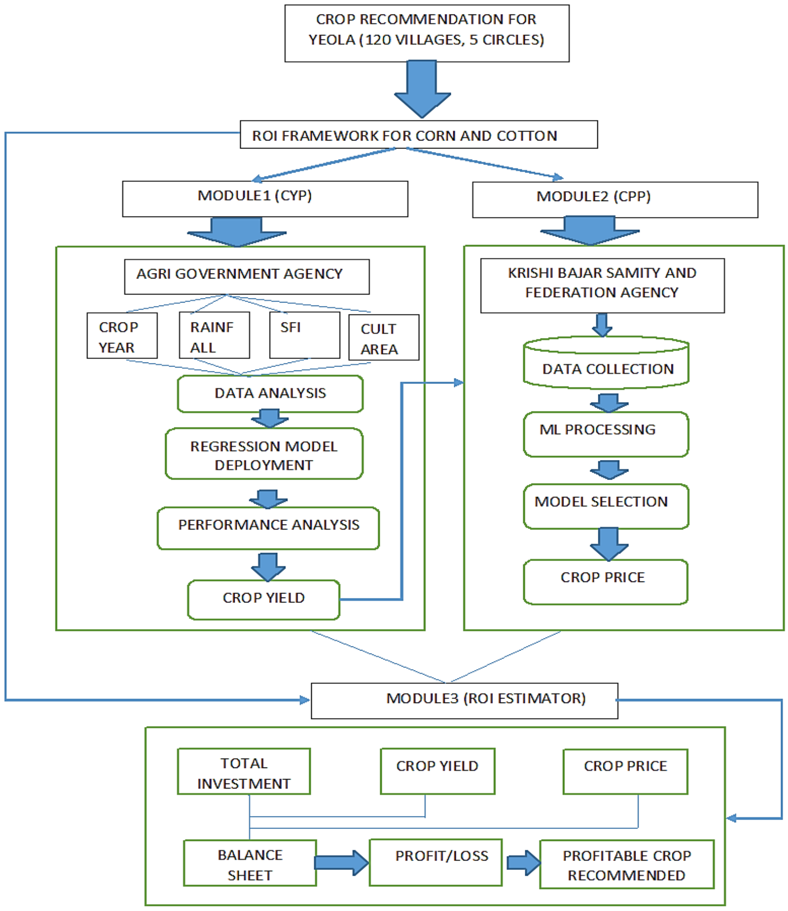

Figure 1. Proposed framework for ROI system

Proposed framework describes that crop recommendation system has been developed for yeola region in which total 121 villages are there which are merged into total 6 circles. This recommendation incudes ROI dimension for crops cotton and corn. ROI value will be calculated by using CYP system and CPP system. Each of this system undergoes data collection from different government agencies and market committee, data analysis for regression statistics, and model deployment for multiple regression algorithms, performance evaluation analysis and final recommendation based on the provided input. Then crop price and crop yield value is used for ROI system. In this system balance sheet has been generated by considering all type of expense cost from initial cropping to final harvesting. Then profit or loss will be calculated to recommend more profitable crop as price [19].

3. RESULTS AND DISCUSSION

In this section, the validation of the proposed ROI framework against existing regression techniques are illustrated with several parameter metrics in our experimental work. In the first subsection evaluation of multiple regression statistics has been done. Further data analysis for significance testing of predictors are evaluated.

3.1. Performance evaluation for identifying optimized machine learning algorithm for crop yield prediction (CYP) system

To design CYP system last three years (2018, 2019, 2020) circle wise data has been collected for yeola region of Nashik district. In this CYP system data has been collected from various digital sources and government agencies for 121 villages from yeola region. All parameters required in data analysis for regression statistics to check significance level testing explained in detail in the reference [20]. Data analysis has been done by using multiple regression statistics in which standard error are calculated as shown in the following Table 1. Then analysis of variance (ANOVA) test has been applied for checking significance level [21] of input parameters such as crop year, rainfall, cultivation area, SFI as shown in Table 2.

Table 1. Evaluation of regression statistics

Regression parameters	Regression statistics
Multiple R	0.99991337
R Square	0.999826747
Adjusted R Square	0.9998253
Standard Error	12.64813767
Observations	484

Table 2. ANOVA test for input features

Parameters	df	SS	MS	F	Significance F
Regression	4	4.42E+08	110553285.4	691064.3	1.16603E-19
Residual	479	76628.21	159.9753866		
Total	483	4.42E+08			

Results of ANOVA test following null hypothesis (H_0) and alternative hypothesis (H_1) has been defined in the following testing. Hypothesis Testing: α=0.05 and P-value should be less than the threshold then only predictors use to predict output are significant as shown in Table 3 otherwise it rejects the null hypothesis.
H0: Crop_Year (β1) =Rainfall (β2) =SFI (β3) =Cultivation_Area (β4) ==0
H1: At least, β1 OR β2 OR β4 OR β3≠0 then ACCEPT H1 and REJECT H0

Table 3. Data analysis for significance testing of predictors

Parameters	Coefficients	Standard error	t Stat	P-value
Intercept	2901.332	6.5836	0.4406	0.0065963
Crop _Year	-1.438531	3.2633	-0.4408	0.65955
Rainfall	-0.000696	0.0078	-0.0888	0.0429219
SFI	0.768672	1.4166	0.5425	0.0015876
Cultivation _Area	3.924554	0.0023	1662.2	0.0362905

Results for significance testing has been observed that overall multiple regression model was significant for (4,479)=F (1.16603E-19), P<0.05, R^2=0.999826747, where α=0.05 then REJECT Null hypothesis H0 and ACCEPT alternative hypothesis H1 for multiple regression equation; (2018, 301, 2.19, 567)=2225.072 Y (Crop Yield)=2901.33+(-1.438531382*Crop Year)+(-0.000696782*Rainfall)+(0.000696782*SFI)+(3.924554098*Cultivation Area)

3.2. Model deployment and performance evaluation of CYP system

Total six machine learning algorithm as sequential minimal optimization regressor (SMO-REG), improved-SMO-regressor (ISMO-REG), multilayer perceptron neural network regressor (MLP-REG), bagging regressor (BAGG-REG), Gaussian regressor (G-REG), random forest regressor (RF-REG), and AdaBoost regressor (AB-REG) has been used for multiple regression to predict accurate yield of the crops [22]. These models are evaluated by using various performance metrics as shown in following Table 4.

And from the results it has been concluded that SMO-REG, ISMO-REG, MLP-REG are giving better performance as compared to other algorithms .But to optimize the results and minimize the error hyper tuning process has been applied on MLP regressor by using stochastic gradient method, learning rate and momentum parameters [23]. Hyper tuning process achieved global minimum error as shown in the following Table 5. From optimized results it has been observed that at the value of learning rate Ƞ=0.5 and momentum M=0.2 root mean squared error (RMSE) error has been minimized to 12.32 from 26.79 and which is the great achievement for us as we have reached to global minima. Graphical representation of hyper parameter tuning results has been presented in the following Figures 2 to 4 for data analysis of regression statistics of crop data set [24].

Table 4. Performance analysis of ML algorithm for CYP

ALGO	COREL-COEF	MAE	RMSE	RAE	RRSE
MLP-REG	0.9996	18.76	26.79	2.93%	2.80%
ISMO-REG	0.9999	5.63	14.025	0.0812%	1.46%
SMO-REG	0.9999	16.85	24.262	2.6386%	2.538%
BAGG-REG	0.9956	19.85	94.699	3.107%	9.9%
G-REG	0.9803	178.9	237.65	28.009%	2.42%
RF-REG	0.9976	17.99	74.045	2.8158%	7.74%
AB-REG	0.7386	435.3	644.41	68.135%	67.41%

Table 5. Optimized results after hyper parameter tuning

TUNNING OF HYPERPARAMETERS(Ƞ,M)→ RMSE			
(0.1,0.1)=26.79	(0.1,0.2)=29.21	(0.1,0.3)=28.32	(0.1,0.1)=27.49
(0.2,0.1)=25.57	(0.2,0.2)=25.10	(0.2,0.3)=24.73	(0.2,0.4)=24.45
(0.3,0.1)=26.66	(0.3,0.2)=26.79	(0.3,0.3)=26.01	(0.3,0.4)=28.52
(0.4,0.1)=29.98	(0.4,0.2)=23.47	(0.4,0.3)=12.52	(0.4,0.4)=12.90
(0.5,0.1)=12.52	(0.5,0.2)=12.32	(0.5,0.3)=12.83	(0.5,0.4)=13.44

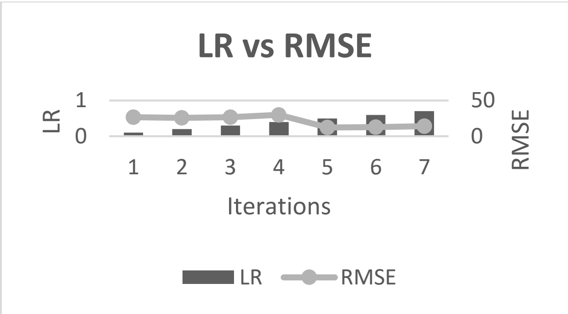

Figure 2. Data analysis for LR (Learning Rate) vs. RMSE

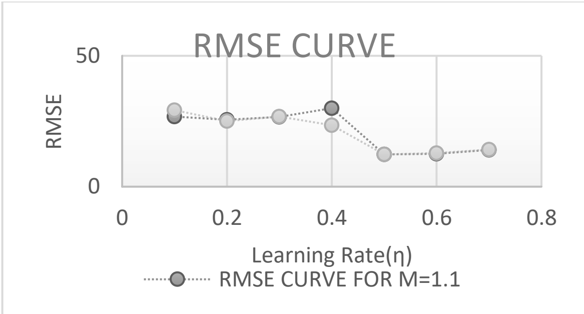

Figure 3. RMSE curve for momentum=1.1 and 1.2

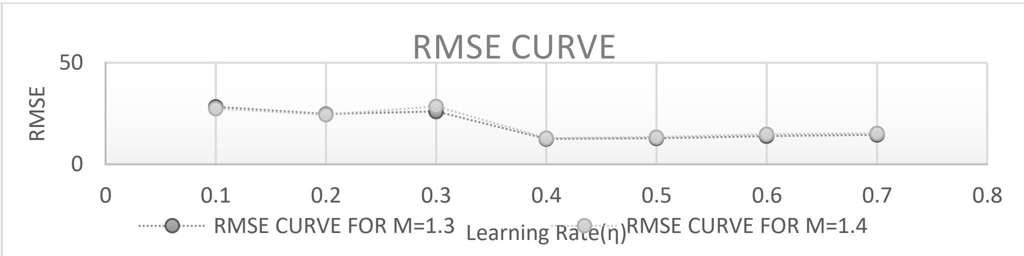

Figure 4. RMSE curve for momentum=1.3 and 1.4

3.3. Results and discussion on performance evaluation for crop price prediction system (CPP)

Process defined for CPP is same as we have seen in previous section. Here only results have been presented in the following tables. Regression statistic analysis demonstrated in the Table 6. Analysis of variance (ANOVA) test has been applied and results has been displayed in the Table 7. Significance and hypothesis testing has been done and results are evaluated in the Table 8. Model evaluation and selection has been done in Table 9.

Table 6. Evaluation of regression statistics for CPP

Regression parameters	Regression statistics
Multiple R	0.999757
R Square	0.999513
Adjusted R Square	0.999511
Standard Error	32.95615
Observations	730

Table 7. ANOVA test for input features for CPP

Parameters	df	SS	MS	F	Significance F
Regression	4	1.62E+09	4.04E+08	372145.29	1.93E-26
Residual	725	787428.4	1086.108		
Total	729	1.62E+09			

Table 8. Data analysis for significance testing of predictors

Parameters	Coefficients	Standard error	t Stat	P-value
Intercept	194.003	27.76939	-6.9862	6.40344E-12
Min_Price	0.188153	0.045594	4.126717	4.10703E-05
Max_price	-0.04276	0.038175	-1.12017	0.263013278
Commodity_Traded_Min	0.48156	0.051445	9.360633	9.73816E-20
Commodity_Traded_Max	0.344199	0.038713	8.890943	4.76037E-18

α=0.05 AND P-value should be less than the threshold then only predictors use to predict output are significant otherwise it rejects the null hypothesis.
Min_Price(β1)=Max_price(β2)=Commodity_Traded_Min(β3)=Commodity_Traded_Max H1:Atleast, β1 OR β2 OR β3≠0 then ACCEPT H1 and REJECT H0.

Table 9. Performance analysis of ML Algorithm for CPP

ALGO	COREL-COEF	MAE	RMSE	RAE	RRSE	Time (sec)
MLP-REG	1	1.7433	2.0	0.1 %	0.1 %	256.32
ISMO-REG	1	4.2731	7.6	0.2 %	0.51%	21.53
SMO-REG	1	6.5401	9.7	0.4 %	0.65 %	72.67
BAGG-REG	0.9999	13.112	21.63	0.8 %	1.45 %	0.08
G-REG	0.9975	339.59	350.58	22.8%	23.7 %	5.04
ADDITIVE-REG	0.9999	14.103	16.97	0.9 %	1.14%	0.07

Graphical representation of Table 9 results has been presented in the following Figures 5 to 9 i.e., performance evaluation analysis for multiple regression model for CPP [25] evaluated by using performance parameters.

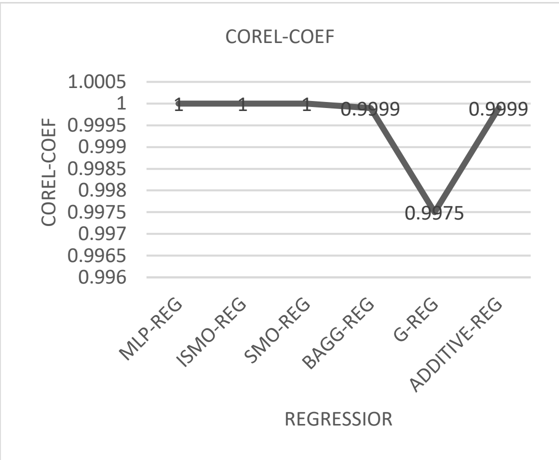

Figure 5. Performance evaluation for COREL-COEF

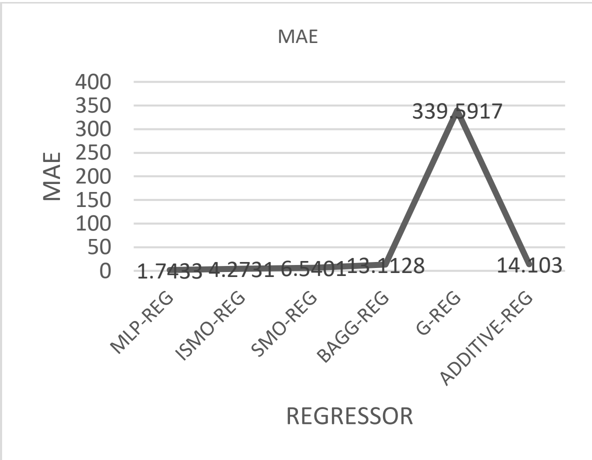

Figure 6. Performance evaluation for mean absolute error (MAE)

3.4. ROI value estimator based on crop yield prediction (CYP) and crop price prediction (CPP) analysis

ROI Estimator module is used to calculate profit and loss by using various expenses cost used for the cultivation of crop by farmers. In this module crop yield and crop price has been taken from CPP and CYP module explained in previous section. For the reference we have considered two crops as corn and cotton for yeola region for our experimental work.

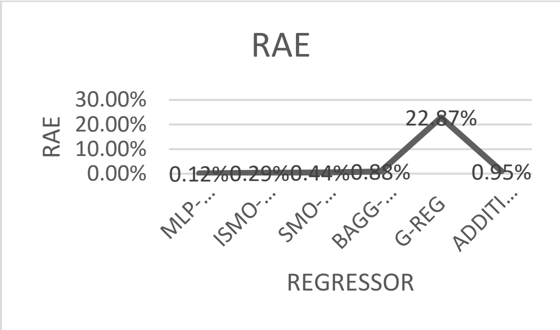

Figure 7. Performance evaluation for root absolute error (RAE)

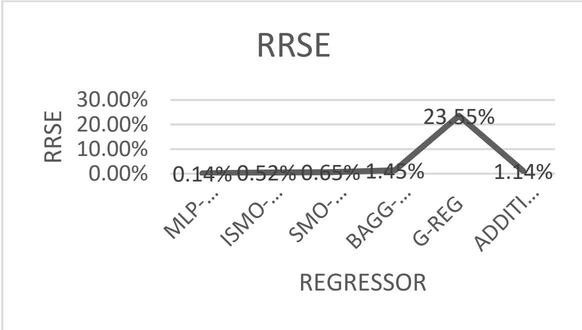

Figure 8. Performance evaluation for root relative squared error (RRSE)

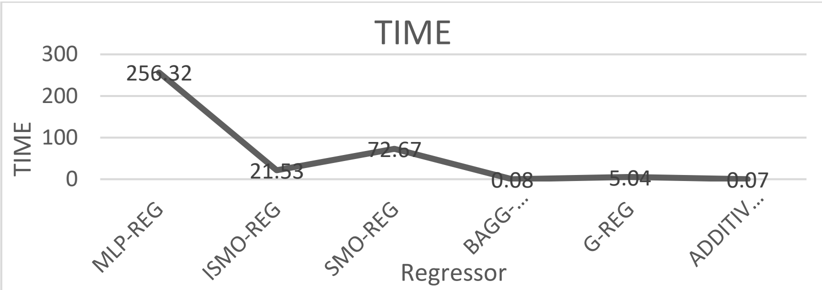

Figure 9. Performance evaluation for time

4. CONCLUSION

ROI framework for profitable crop recommendation system has been developed by using optimized MLP regressor algorithm. By applying stochastic gradient decent (SGD) method and hyper tuning parameters i.e., learning rate (Ƞ) and momentum (M) process, RMSE is minimized to 12.32 from 26.79. And data analysis has been applied to get accurate regression statistics which helps us to select appropriate model for crop recommendation system. Knowledge-based agriculture system is continuously benefiting our earth and helping people in various aspects of life in terms of crop management and yield improvement.

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BIOGRAPHIES OF AUTHORS

Prof. Surekha Janrao is working as an assistant professor in Terna Engineering College, Navi Mumbai from 2010. She has done her bachelors and master's in computer engineering from Mumbai University. She has published more than 8 papers in international journal. Her area of interest is Machine Learning, Data Mining, IoT. She is Research scholar and doing research in Machine learning and IoT under the Guidance of Dr. Deven shah. She can be contacted at email: surekhajanrao@ternaengg.ac.in.

Dr. Deven Shah is a professor working as the Vice-Principal of Thakur College of Engineering and Technology, Mumbai. He is a techie having 25 years of experience in corporate as well as academia. Dr. Deven Shah has served as Principal during previous tenure and has the honorary position of Chairman, Board of Studies (Information Technology) in University of Mumbai. His research work is commendable, and he has filed five patents. During his tenure in industry, he has served as All India Technical Head of the MNC, handling various clients in networking domain. His work in industry was accorded with Best Employment Award. He can be contacted at email: sir.deven@gmail.com.