Journal of Computer Applications Research and Development (JCARD), ISSN 2248-9304(Print), ISSN 2248-9312 (Online), Volume 1, Number 1, April-June (2011)
pp. 35- 42 © PRJ Publication
http://www.prjpublication.com/JCARD.asp

JCARD

© PRJ PUBLICATION

COMPARISON OF MEMBERSHIP FUNCTIONS IN ADAPTIVE-NETWORK-BASED FUZZY INFERENCE SYSTEM (ANFIS) FOR THE PREDICTION OF GROUNDWATER LEVEL OF A WATERSHED

M. Kavitha Mayilvaganan[1], K.B.Naidu[2]
[1]Research Scholar, [2]Professor, Department of Mathematics,
Sathyabama University, Chennai, India
m.kavithaa@gmail.com

ABSTRACT

In this study, Adaptive-Network-Based Fuzzy Inference System (ANFIS) approach, introduced by Jang (1993) was employed to investigate its applicability in predicting water level in Thurinjapuram watershed, Tamilnadu, India. The ANFIS combines the explicit knowledge representation of Fuzzy Inference System with the learning power of Artificial Neural Networks, therefore it is a very powerful approach to build complex relationship between a set of input and output data. It also provides a natural framework for combining both numerical information in the form of input/output pairs and linguistic information in the form of IF–THEN rules in a uniform fashion. The results of the modeling were reasonable in terms of statistical performances. Several indices of performance such as mean average error, root mean squared error, and coefficient of correlation showed good performance. The results were compared with different type of membership function. The model with Gaussian membership functions gave the best performance among all given models. The capability ANFIS system in producing such reasonable result indicated that this approach has potentially to be used as predictor of water level in the Thurinjapuram watershed, Tamilnadu, India.

Key words: ANFIS, Membership functions, Groundwater level, MATLAB, Observation wells, Watershed.

I. INTRODUCTION

Recently, intelligent soft computational techniques such as Artificial Neural Network (ANN), Fuzzy Inference System (FIS) and (ANFIS) can model superiority of human knowledge features. They also re-establish the process without plenty of analysis. Thus these techniques are attracting great attention in an environment that is obvious with the absence of a simple and well-defined mathematical model. Besides, these models are characterized by nonrandom uncertainties which associated with imprecision and elusiveness in real-time systems [2-3]. Many researchers have studied the application of neural networks to overcome most of the problems above outlined. The fuzzy set theory is also used to solve uncertainty problems. The use of neural nets in applications is very sparse due to its implicit knowledge representation, the prohibitive computational effort and so on. The key benefit of fuzzy logic is that its knowledge representation is explicit, using simple IF-THEM relations. However, it is at the same time its major limitation. The groundwater level prediction cannot be easily described by artificial explicit knowledge, because it is affected by many unknown parameters. The integration of neural network into the fuzzy logic system makes it possible to learn from the prior obtained data sets [4-5].

This research employs adaptive-network-based fuzzy inference system for the prediction of groundwater level of a watershed. This novel approach overcomes the difficulties associated with conventional methods. This research is integrating the learning capabilities of neural network to the robustness of fuzzy logic systems in the sense that fuzzy logic concepts are embedded in the network structure. It also provides a natural framework for combining both numerical information in the form of input/output pairs and linguistic information in the form of IF–THEN rules in a uniform fashion. Modern artificial intelligence methods such as neuro-fuzzy systems can be used for forecasting. These methods provide fast, reliable and low-cost solutions. Another advantage of these methods is that they can handle dynamic, non-linear and noisy data, especially when the underlying physical relations are very complex and not fully understood. The purposes of this study are to investigate the applicability of ANFIS in predicting water level in Thurinjapuram watershed and to identify the most fitted model to the study area.

II. DESCRIPTION OF STUDY AREA

The Thurijapuram watershed covers geographical area of 151.38 sq. km and is located in between 12°12'58" and 12° 21'11" North latitudes and 78°59'45" and 79°9'28" East longitudes (Fig. 1) It is mainly situated in Thiruvannamalai district of Tamilnadu, India. It is mainly located in Thurinjapuram block (in India, a block is a group of villages, an administrative sub-division of a taluk.) and partially falls into two other blocks (Chengam and Thiruvannamalai). Thurinjalar is one of the major tributaries of Ponnaiyar major river originating from Kavuttimalai reserve forest in Chengam Taluk of Tiruvannamalai district. It flows in south-southeast direction of the basin crossing Thurinjapuram, Kilpennathur and Tiruvannamalai blocks and confluences with Ponnaiyar river near Thirukkoilur after flowing a distance of about 44 kms. Thurinjalar River, which is the major stream draining the area, exhibits only sporadic flow during the rainy season. The drainage characteristics are very good. Bedrock is peninsular gneiss of Archean age. The Thurinjapuram area can be classified as ''hard rock terrain''. The predominant soil types in this river basin are Entiso, Inceptisols, Vertisol and Alfisols. The soil in this minor basin is observed to have good infiltration characteristics. Hence groundwater recharge is possible in this area.

The climate is semi-arid. May is the hottest month with a maximum temperature of up to 41° C and December is the coolest month with a maximum of 21.6° C. The climate of the area is characterized by four distinct seasons, namely southwest monsoon (Jun –Sep), northeast monsoon (Oct – Dec), winter season (Jan – Feb) and hot summer season (Mar - May). Hydro meteorological data were collected from Kilnatchipattu weather station maintained by State Ground & Surface Water Resources Data Centre, W.R.O, and P.W.D. The economy of the Thurinjapuram sub watershed depends mainly on agriculture. Data from three observation wells, which have been monitored on a monthly basis by the Department of Groundwater, are available in the Thiruvannamalai Groundwater subdivision.

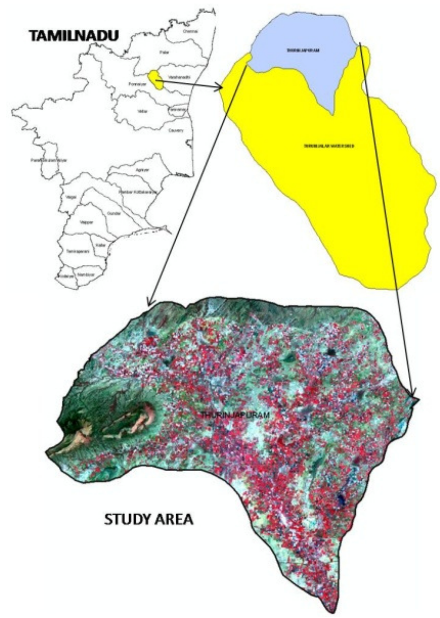


Fig. 1 Study area

A. Data

The input data used for water level prediction are monthly Rainfall RF(k) and Ground water (level in the observation well) data WL(k) of Thurinjapuram watershed in Tamilnadu, India, and one month ahead groundwater level WL(k+1) as output. For the present study monthly water level data for three observation wells (23112, 23142, and 23143) during 1985 to 2008 has been collected from Thiruvannamalai Groundwater subdivision. In the same period monthly Rainfall data were collected from Kilnatchipattu Raingauge station.

III. THEORY AND METHODOLOGY

Adaptive Network-Based-Fuzzy Inferences System (ANFIS) approach was employed in this study. The ANFIS architecture consists of fuzzification layer, inferences process, defuzzification layer, and summation as final output layer. Typical architecture of ANFIS is shown by Fig 2. The process flows from layer 1 to layer 5. It is started by giving a number of sets of crisp values as input to be fuzzyfied in layer 1, passing through inference process in layer 2 and 3 where rules applied, calculating output for each corresponding rules in layer 4 and then in layer 5 all outputs from layer 4 are summed up to get one final output. The main objective of the ANFIS is to determine the optimum values of the equivalent fuzzy inference system parameters by applying a learning algorithm using input-output data sets. The parameter optimization is done in such a way during training session that the error between the target and the actual output is minimized. Parameters are optimized by hybrid algorithm which combination of least square estimate and gradient descent method. The parameters to be optimized in ANFIS are the premise parameters which describe the shape of the membership functions, and the consequent parameters which describe the overall output of the system. The optimum parameters obtained are then used in testing session to calculate the prediction [6]. A number of 192 data were utilized during training session and 84 data were used during testing session.

In this study, basic model is constructed by 2 inputs and 1 output. The inputs are rainfall data and water level data and one month ahead groundwater level as output. The basic model then varied in 8 different types of membership functions. For computational purposes, some Matlab programming codes have been developed, to compute different types of membership function, but most of the times, fuzzy toolbox is used [1].

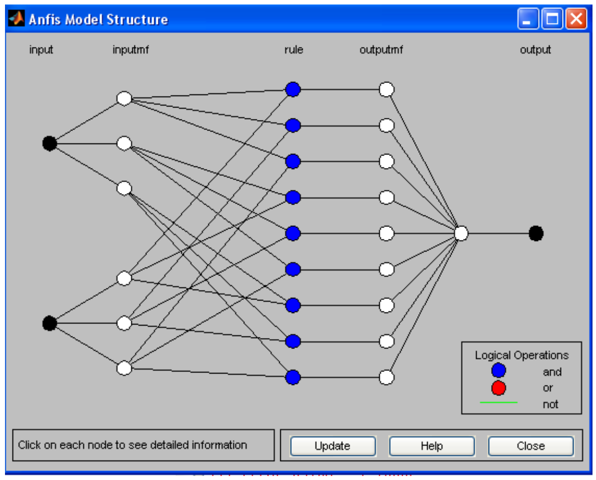


Fig 2.ANFIS Model

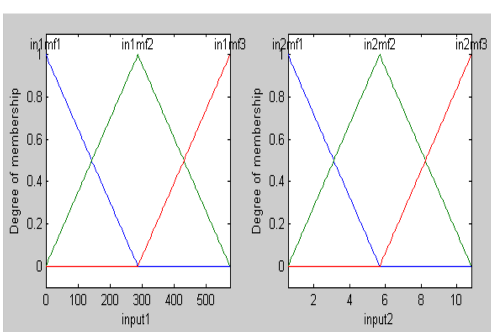
A. ANFIS model

ANFIS info:

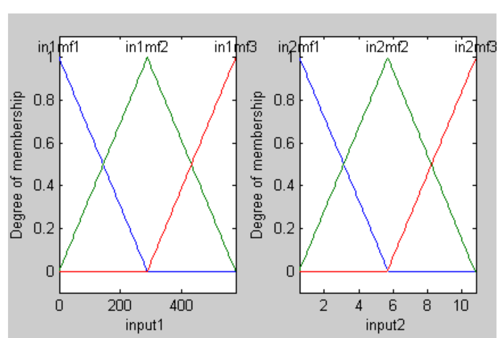
- Number of nodes: 35
- Number of linear parameters: 27
- Number of nonlinear parameters: 12
- Total number of parameters: 39
- Number of training data pairs: 192
- Number of testing data pairs: 84
- Number of fuzzy rules: 9
- Number of epochs: 150

B. Comparison between Membership Functions

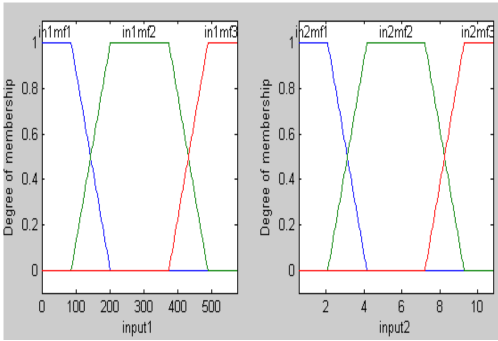
Depend upon the model and combinations, the ANFIS system produced different results. To find the most fitted model, the results are compared and discussed as follows. The changes in the MFs before and after training are shown in the following fig



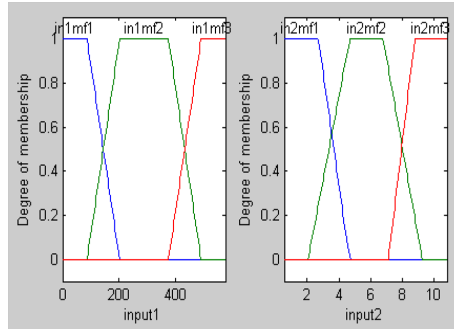
Initial trimf for inputs RF (k), WL (k)



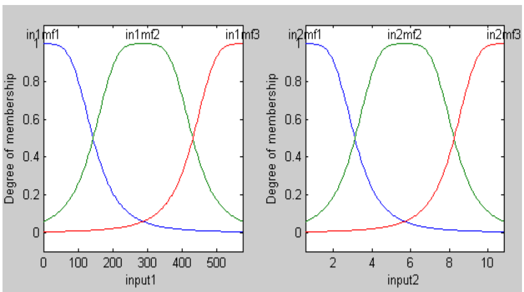
Final trimf for inputs RF (k), WL (k)



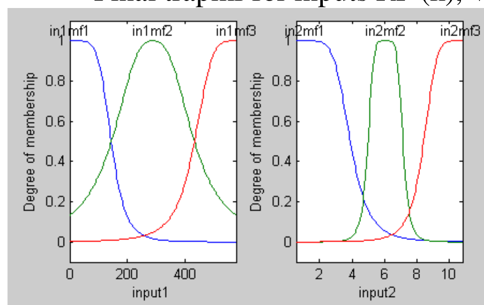
Initial trapmf for inputs RF (k), WL (k)



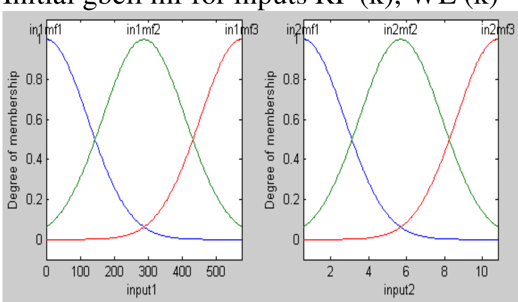
Final trapmf for inputs RF (k), WL (k)



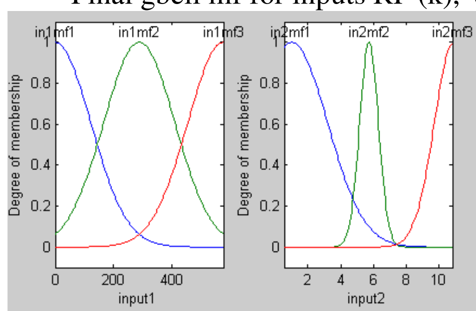
Initial gbell mf for inputs RF (k), WL (k)



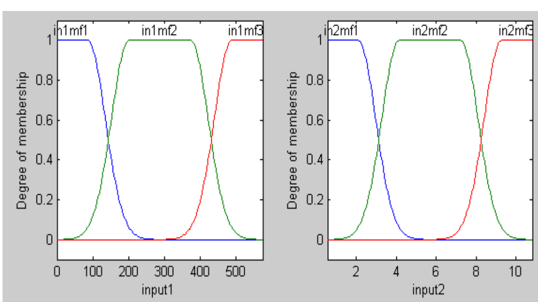
Final gbell mf for inputs RF (k), WL (k)



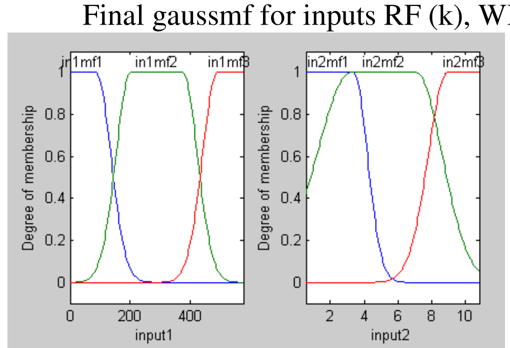
Initial gaussmf for inputs RF (k), WL (k)



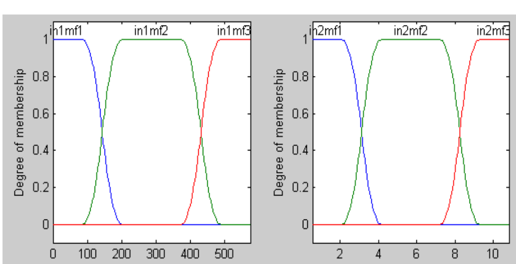
Final gaussmf for inputs RF (k), WL (k)



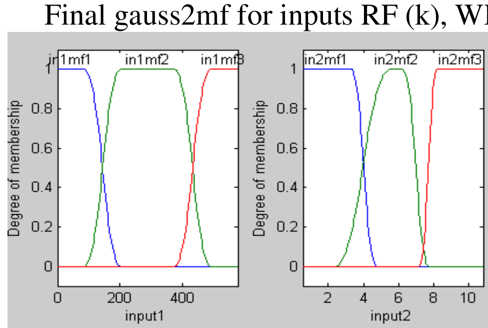
Initial gauss2mf for inputs RF (k), WL (k)



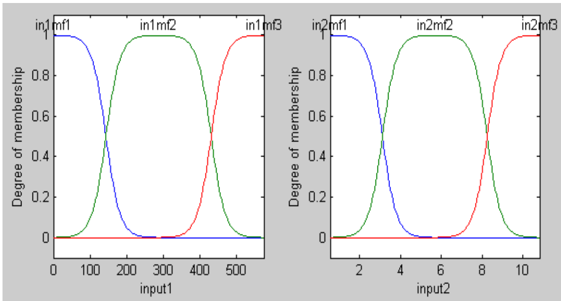
Final gauss2mf for inputs RF (k), WL (k)



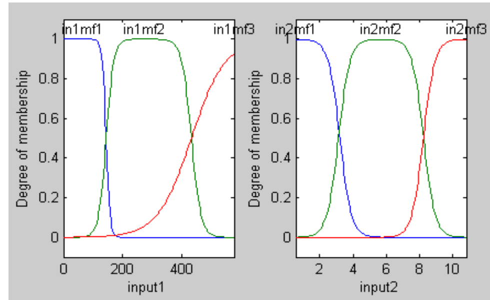
Initial pimf for inputs RF (k), WL (k)



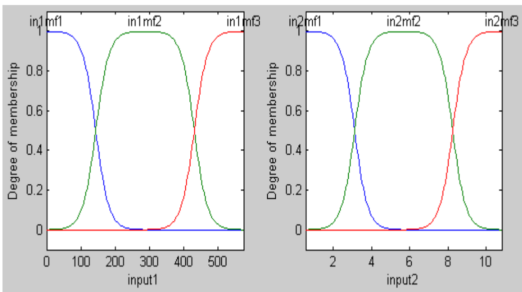
Final pimf for inputs RF (k), WL (k)



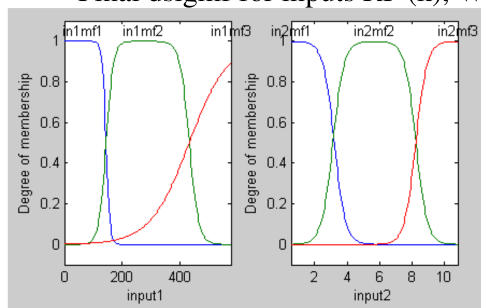
Initial dsigmf for inputs RF (k), WL (k)



Final dsigmf for inputs RF (k), WL (k)



Initial psigmf for inputs RF (k), WL (k)



Final psigmf for inputs RF (k), WL (k)

Fig3.The changes in the trapezoidal MFs before and after training. (a) Initial mf for inputs RF (k), WL (k) (b) Final mf for inputs RF (k), WL (k)

All RMSE and peak errors (minimum and maximum) results, processed with different type of membership functions, are listed in descending order in Table 1 for comparison purposes. It was found that the groundwater level prediction of watershed vary to great extent between the various MFs however the best prediction was obtained when using the Gaussian MF. The bell MF, and the two sided Gaussian MF are only slightly poorer than the Gaussian MF. Remaining MFs are poorer still than the above-mentioned MFs. The poorest MF is the trapezoidal MF.

ANFIS system is sensitive to number of membership function. Giving additional number of membership function to the system did not always improve the result. For those models, by increasing number of membership function from 2 to 3 the results are better. But by increasing number of membership function from 3 to 4, in most cases the performances are decreasing. Applying 3 number of membership function gave the best results.

Table 1. Comparison between Membership Functions

MF	RMSE	MIN(e)	MAX(e)
trapmf	1.90909	-5.55557	5.169278
dsigmf	1.87549	-5.30406	4.646568
trimf	1.87542	-5.00942	4.739511
psigmf	1.87539	-5.34203	4.612559
pimf	1.8685	-4.71322	5.276592
gauss2mf	1.82056	-5.25698	4.833183
gbellmf	1.80235	-4.64138	5.170838
gaussmf	1.8021	-4.58066	5.118948

ANFIS uses either a hybrid learning algorithm or the back-propagation method to identify the MF parameters of the output. A combination of least-squares and back propagation gradient descent methods can be used for training fuzzy inference system (Sugeno type FIS) membership function parameters to model a given set of input/output data or just the back-propagation method. Average errors of groundwater level of a watershed as predicted by using the back-propagation method and by using the hybrid learning algorithm are shown in Table 2. From this table, the capability of the ANFIS model in predicting the groundwater level using the hybrid learning algorithm is much better than when using the back-propagation method. This is because the hybrid method comprises of back propagation and Least-Square methods.

Table 2 Average Errors by the Back-propagation Method and the Hybrid Learning Algorithm

Method	Average training error	Average testing error
Hybrid	1.8576	2.4369
Back propagation	1.9023	2.4530

IV. RESULTS AND DISCUSSION

In terms of statistical performances, three indices including mean average error(MAE),root mean squared (RMSE), coefficient of correlation (R), are also used to find the most fitted model. The ANFIS model for all the three wells are compared based on their performance in training sets and testing sets. The results are summarized in Table 3.It appears that the ANFIS models are accurate and consistent in different subsets, where all the values of RMSE and MAE are smaller, and all correlation coefficients(R) are also very close to unity. ANFIS model maintains its excellent prediction accuracy throughout the range of water level, hence showing consistency and high a degree of generalization capability.

Table 3 MAE, RMSE and R goodness of fit criterions for the ANFIS model

Sl.no	Well no	Criterion	MAE	RMSE	R
1	23112	Testing	0.23	0.23	0.99
2	23141	Testing	0.16	0.45	0.98
3	23143	Testing	0.41	0.57	0.97

V. CONCLUSION

In this study, we propose the use of a novel neurofuzzy model, the adaptive network-based fuzzy inference system (ANFIS), to construct water level forecasting system. ANFIS is a powerful fuzzy logic neural network, which provides a method for fuzzy modeling to learn information about the data set that best allow the associated fuzzy inference system to trace the given input/output data. In this study water level in the Thurinjapuram watershed was predicted by using ANFIS Method. Model with 3 membership function of Gaussian function has given the best performance and the results clearly illustrated that ANFIS has the potential for modeling in hydrologic time series to predict water level of a watershed by applying appropriate membership function and the number of membership function.

ACKNOWLEDGEMENT
The First author gratefully acknowledges the support given by DST Govt. of India, New Delhi, under Women Scientist Scheme.

REFERENCES

[1]. MATLAB R2008a, 2008 The Math Works, Inc. (MATLAB and Simulink are registered trademarks of The Math Works, Inc.)

[2]. ASCE Task Committee on Application of Artificial Neural Networks in Hydrology. Artificial neural networks in hydrology I: Preliminary concepts. Journal of Hydrologic Engineering 2000; 5(2):115–23.

[3]. Liao HP, Su JP, Wu HM. 2001, An application of ANFIS to modeling of a forecasting system for the demand of teacher human resources. J Educat Psychol; 24(1):1–17.

[4]. Govindaraju RS, Rao AR. 2000, Artificial neural networks in hydrology, Dordrecht: Kluwer Academic Publishers.

[5]. Ponnambalam K, Karray F, Mousavi SJ. 2003, Minimizing variance of reservoir systems operations benefits using soft computing tools, Fuzzy Sets Syst; 139:451–61.

[6]. Fi-John Chang , Ya-Ting Chang ,2006 ,Adaptive neuro-fuzzy inference system for predictionof water level in reservoir, Department of Bioenvironmental Systems Engineering and Hydrotech Research Institute, National Taiwan University, , Taiwan, Advances in Water Resources 29 - 1–10

AUTHOR BIOGRAPHIES

M.Kavitha Mayilvaganan post graduated in Mathematics from Madras University, India She is currently pursuing PhD at SathyabamaUniversity, Chennai, India. She has published 6 papers in national & international conferences and 3 papers in international journals. Her research interest includes Soft computing and GIS.
Email ID.m.kavithaa@gmail.com

Dr.K.B.Naidu post graduated in Pure and Applied Mathematics from S.V.University, Tirupathi, India and PhD from IIT Madras. He is currently working as Professor at the Faculty of Department of Mathematics, Sathyabama University, Chennai, India. He has published more than 40 papers in national & international journals and published 2 chapters in the book titled Mathematical Physiology and Biology published by Cambridge University Press U.K. He has 39 years of teaching experience in Pure and Applied Mathematics. He guided 18 candidates for PhD and M.Phil. Presently guiding 5 candidates for Ph.D. His research interest includes Modeling in Science, Technology and Medicine.
Email ID.kbnaidu999@gmail.com