Simulation of Groundwater by using Support Vector Model and Comparing That with the Neuro-Fuzzy Model (ANFIS) :

(Case Study Neyriz Plain)

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Abstract
Undoubtedly, the best way for recognition of qualitative treatments of groundwater resources is conducting long time researches, gathering the basic data for long periods and obtaining results from these data.
In this research, the efficiency of support vector model (SVM) and the neuro- fuzzy inference system (ANFIS) was investigated for simulation of groundwater level based on the available data in a 19 statistical period including precipitation and the average of groundwater level (since 1994 since 2013).
In the present research, the different scenarios were reviewed for intelligent inputs models; and the performance of above mentioned models was investigated based on the statistical indexed such as correlation coefficient (R) and mean square error (MSE).
Finally, the suggested results of proper performance of both support vector models of (MSE=0.0001and R=0.9867) and ANFIS (MSE=0.0003, R=0.9820) in simulating the plain groundwater level are considered.
Keywords:
groundwater level, support vector model (SVM), Neuro-Fuzzy Inference System (ANFIS)

1. Introduction

The groundwater is as one of the most important sources of providing fresh water required by human. Nowadays, explosion of groundwater for the consumptions such as agriculture, industry and drinking has highly developed. So, forecasting the groundwater level may have a significant effect on the management of groundwater. The different models such as mathematic, statistic and … have used for predicting the groundwater level that the purpose of present research is investigation of intelligent models in this regard.
Kholghi et al. (2009) by using the Stochastic and ANFIS models reviewed the monthly drought in Gilan Navrood catchment.
Esmi- Khani et al. (2010) studied on the consolidated management of surface water resources and groundwater by using the support vector machine methods as well as the genetic algorithm in the catchment of Zayandeh Rood.
In 2011, Mirzaei and Nazemi studied on the anticipating the water table level of Shabestar plain by using the intelligent systems. In these studies, the results suggest the proper performance of intelligent models in this regard.
Based on another study, Rezaei et al. (2013) proceeded to study on designing the groundwater level monitoring network by using the support vector squares minimum (LS-SVM) in Raamhormouz plain zone. Fereydooni and Zahedi (2014) investigated the ability of artificial neural network and comparative ANFIS in simulating the groundwater level of Arsenjan plain. The results of this research suggest the proper performance of comparative ANFIS in the considered plain.
Setoodeh Pour and Fereydooni (2014) by using the ANFIS and stochastic models simulated the groundwater level of Jam plain; that again the more suitable results were obtained by ANFIS intelligent model.
In 2016, Mobaraki and Fereydooni by using the combination of wavelet functions and the ANFIS model investigated the simulation of groundwater level of Neyriz plain; and the results were compared with the neuro-fuzzy modeling.
According to another research conducted by Fereydooni and Borujerdi (2015) regarding the simulation of Shiraz plain groundwater level, the results suggest the proper performance of neural wavelet model in comparison with the support vector and neuro- fuzzy models.
Bishat et al. (2009) by using the fuzzy logic and neural-fuzzy models simulated the fluctuation of water surface level in …..In 2011Amiuta et al. studied on seasonal prediction of groundwater surface in Molatar basin located in the Vellor region, Tamalandi of India by using the neural- fuzzy and the neural networks models.
Based on another study in 2014, Yuma Masouri and Kalamani investigated the fuzzy logic model for forecasting the groundwater surface in Amarvathi basin located in Indian subcontinent. Li Tang Shu et al. (2015) proceeded to modeling the neuro-fuzzy and predicting the water resources.
In 2015, Jing Feng et al. started to compare the performance of ANFIS for simulation of flow in the area under the effect of southern fluctuation of Elnew. Generally, in all conducted studies the intelligent models have indicated

Manuscript received June 5, 2017
Manuscript revised June 20, 2017

proper performance in simulation of the considered hydrologic parameters.
In this research, it has been attempted that by using the hydrograph information and statistics of Neyriz plain unit as well as the statistics of monthly precipitation of … station in a 19 years period (1994- 2013), the performance of support vector models and ANFIS to stimulate the groundwater level of Neyriz plain to be studied.

2-Materials and methods

2-1- The understudied region and data:

Neyriz plain has located in the eastern basin of Fars province and in the geographical coordinates of 54 ° and 5' to 54° and 32' of eastern longitudes and 29° and 2' to 29° and 26' of northern latitude and in the east of Bakhtegan lake.
This basin from northward is limited to Tashk lake basin and the heights of Dal-Neshin, from southward to Ghatroyeh basin and the heights of Palangan and from Westward to Bakhtegan Lake.
The area of Neyriz central plain basin is about 984.6 Km² in which approximately 358 Km² of it, is the plain and the rest is mountain regions. In addition, the area of aquifer of Neyriz is equal to 238.67 Km². The most height of basin is 2818m in Ghebleh mountain summit and the least is 1555 m by the Bakhtegan Lake; and the average of plain height is 1560m from the sea surface. The distance of Neyriz to the center of province (Shiraz) is 225km.

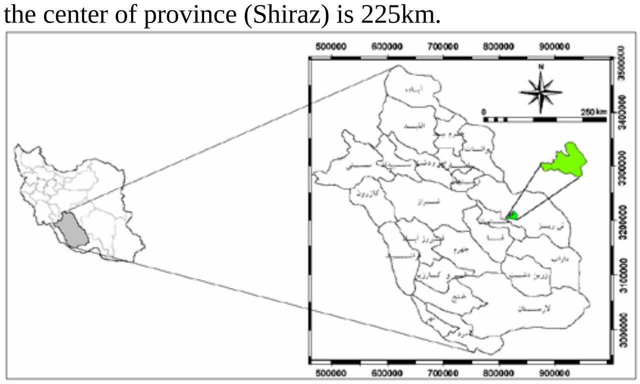

Fig 1: the loacation of Neyriz County on the map

2-2- Models theory

2-2-1- Concepts and theory of the comparative ANFIS:

The ANFIS is as a multi-layer feed forward network using the neural network learning algorithms and uses the fuzzy logic to draw an input space to an output space.
These systems have desire ability in training, making and classifying; in addition are able to exploit the fuzzy laws from the numeral information as well. In the ANFIS, firstly, by considering the kind and number of membership functions as well as the type of data, the structure of model is designed; then by using the artificial neural network training algorithms, the parameters of setting membership functions that results in training the model and presenting the rules governing the relationship between inputs and target data. Among the most important functions are triangular, trapezoidal, Gaussian and belled.
In terms of structure, a neuro- fuzzy consists different layers. In the first layer (input) the allocated amount of each input to different fuzzy period is determined; then by multiplying the input values to each node into each other, the weight of laws is obtained in the second layer; in the third layer, the calculation of laws relative weight is done based on the relation …. The fourth layer is laws layer that is obtained from performing the operations on the input signals to this layer; and finally, the fifth layer is the same as the output layer; and its objective is to minimize the obtained output difference from the network and the real data. The Fig …. Shows the structure of ANFIS.

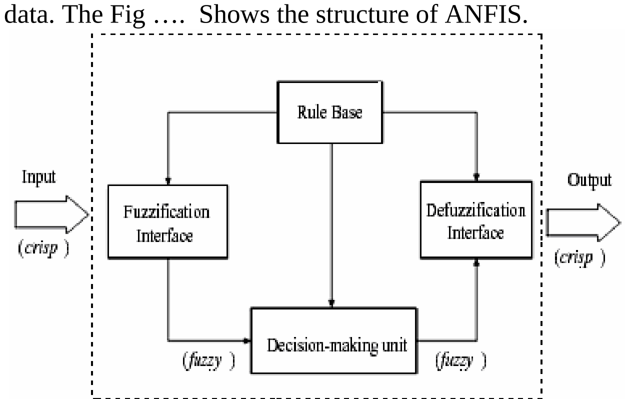

Fig2: the structure of a fuzzy system

2-2-2- The concepts and theory of support vector model

The support vector models are as one of the artificial neural network models that are able to classifying the linear and nonlinear patterns; as well as estimating the functions and predicting the time series. For the first time this model was introduced by Vepnic and Cortes in 1995. Gradually, it was used in different sciences. These models, unlike the other models of artificial neural network such as multi-layers Perceptron and the radial basic functions have considered the operational risk as the target of function; and estimate the optimum amount of it.
The SVM classifiers work based on the linear classification of data; and in linear classification of data, it is attempted that a line with more safety margin to be selected. Solving the equation of finding the optimum line for data is done by QP methods that are as the known methods in solving the limited problems.
In non-linear classifications, one series of Cornel functions are used that among them is the functions of linear, multi

polynomial, radial basis functions and Gaussian (Elham Kakaei et al.).The Fig 3 … shows the linear separation of a support vector model.

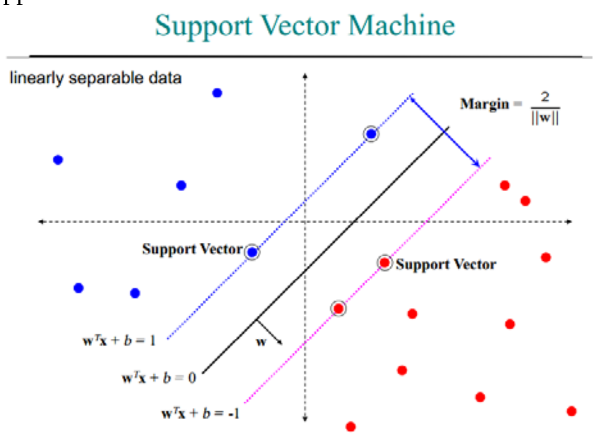

Fig3: the structure of support vector machine.

3. The model evaluation criteria

For evaluating and determining the efficiency of used models, the statistical indexes such as root mean square error (RMSE) and the correlation coefficient of R have been used, in which this amounts are calculable by relations of... and ...

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(Oi - Ti)^2}{N}}$$

$$R = 1 - \frac{\sum_{i=1}^{n}(Oi - Ti)^2}{\sum_{i=1}^{n}\left(Oi - \overline{Oi}\right)^2}$$

In above-mentioned relations Oi and Ti are as the observational and output values of models respectively; and $\overline{O}$ is as observational values mean and N is the total number of data.

4. Discussion and conclusion

In this research, the efficiency of support vector models (SVM) and neural – fuzzy inference system (ANFIS) have been used to simulate the level of groundwater based on monthly data of a 19 years statistical period including precipitation and the average of groundwater level of Neyriz plain (since 1994 to 2013).
For this purpose, firstly, it is needed that for increasing the speed and reduction of error as well as equalizing the value of data for network, the operation of normalization to be done (data are between zero and one). After normalizing the data, the input patterns of model are specified; that in the present study are as follows:
(W) (P-1) (W-1) and (W) (W-1) and (W) (W-2) (W-1) and (P-2) ، (P-1) ، (W-2) ، (W-1)

In these patterns W is as groundwater marker and P is the marker of monthly precipitation. In each pattern, 80 percent of data has considered as the training and 20 percent are as the model test.

4-1- The modeling results of ANFIS

For modeling in the neuro- fuzzy systems, the available toolbar of the Matlab software has been used that is designed for this purpose. In this regard, the different membership functions such as triangular, trapezoidal, Gaussian and belled membership functions have been used in the model structure; and the multilayer feed forward neural network with the hybrid training algorithm and Takagi-Sugeno-Kang AFIS have been used for training the model.
The neuro- fuzzy optimum system is obtained by continues changing in the type and the number of membership functions as well as the number of repeats for the adjustment of membership functions parameters. In table 1 the results of best model and most proper effective parameters on groundwater level of considered plain have come.

Table1: The obtained results of groundwater level simulation by using the ANFIS for each of 4 patterns

ANFIS			
Patterns	R	MSE	MF TYPE
(P-1) و (W-1)	0.9530	0.0026	Trimmf
(W) و (W-1)	0.9789	0.00042096	Guss2mf
(W) و (W-1,W-2)	0.9820	0.00031008	Guss
(W) و (W-1,W-2)(P-1,P-2)	0.9708	0.00037836	Trapmf

Although the patterns of (W) and (W-1,W-2) have the highest accuracy and the least error in the simulation of groundwater level; but it can be said that overall the neuro-fuzzy model has shown an appropriate performance in all four pattern.
The 4 and 5 Figs respectively show the diagrams of real and simulated values as well as the regression diagram in the (W) and (W-1,W-2) pattern.

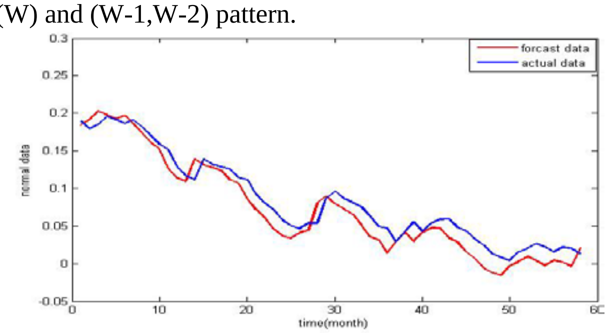

Fig4: The diagram of comparing the calculated and observed data of the best neuro- fuzzy model pattern.

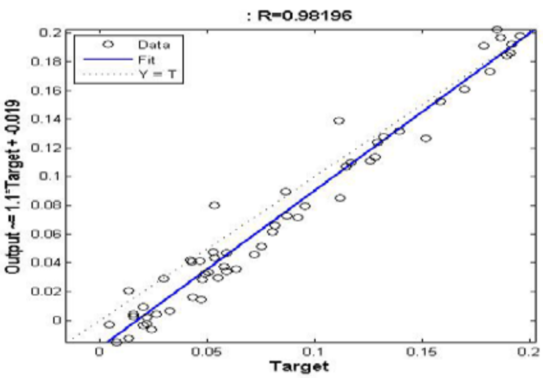

Fig5: The regression diagram of the best pattern of neuro- fuzzy model

The results of support vector machine modeling (SWM)

For simulating, the different functions of Cornel were used that one of the most appropriate of them is radial basic function (RBF). The simulation results of this model are shown in table 2.

Table 2: the obtained results of simulation groundwater level by using the support vector model for each of 4 pattern

SVM		
patterns	R	MSE
(P-1) و (W-1)	0.9848	0.000133
(W) و (W-1)	0.9789	0.0012
(W) و (W-1,W-2)	0.9815	0.000906
(W) و (W-1,W-2)(P-1,P-2)	0.9867	0.0001226

As it is shown in table, the support vector model has shown the appropriate performance in simulation of groundwater level in each four pattern. In the following, the regression diagram as well as observational values diagram against the real values have been specified in the Figs 6 and 7.

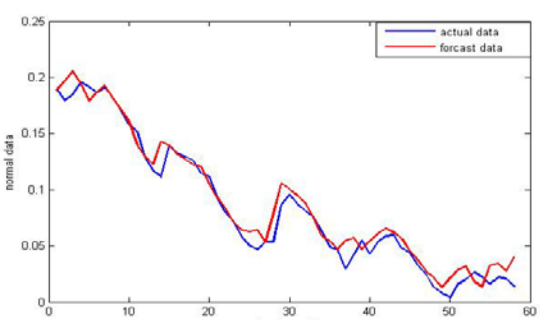

Fig 6: The diagram of comparing calculated and observed water level of the best pattern of support vector model

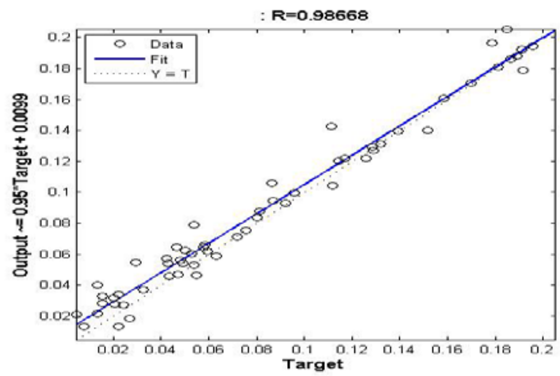

Fig7: The regression diagram of the best pattern of support vector model

Conclusion

In this research, the operation of neuro- fuzzy models and the support vector for simulation of groundwater level were used in which the results suggest the proper operation of both models with the negligible error percent. In addition, different patterns were considered to achieve the appropriate inputs for model.

Finally, the (W) pattern and (W-1,W-2)(P-1,P-2) with the most correlation coefficient (0.9867) in the support vector model and the patterns (W) and (W-1,W-2) with the most correlation coefficient (0.9820) in the neuro-fuzzy model were considered as the most appropriate pattern.

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