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Modeling an Application for Oil and Gas Ratio Prediction Using ANFIS

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Abstract

The basic advantage of Adaptive Network-based Fuzzy Inference Systems (ANFIS) technique is that it provides a set of rules that can be helpful in the understanding of the problem under study. More than one application is approved on petroleum domain by using BPNN and FNN techniques. This paper updates a novel application for Oil and Gas ratio prediction using ANFIS technique. The application test and evaluate the result of crude oil dataset prediction on 30 wells of Daqing oilfield. Experimental result on crude oil prediction field shows that ANFIS achieves better result than other techniques.

Keywords: *Adaptive Network-based Fuzzy Inference Systems, Crude Oil, Prediction.*

1. Introduction

In a few recent years, there are more than one theoretical research about prediction process on many domains has been increasingly developed in order to use it in applied aspects, crude oil (petroleum) is one of necessary source energy around the world, crude oil prediction have its importance through people need of energy [1]. There are a variety of techniques to predict whether a particular area of crude oil would be presence in the future. Crude oil is a naturally occurring, flammable liquid consisting of a complex mixture of hydrocarbons of various molecular weights and other liquid organic compounds, that are found in geologic formations beneath the earth's surface. Presences of crude oil interpreted underneath within sedimentary rock and undergo intense heat and pressure [2]. This interest has been specially displayed much more in the development of intelligent systems which are based on the empirical data. A neuro-fuzzy system, which combines neural networks and fuzzy logic, has recently garnered a lot of interest in researches and application [3].

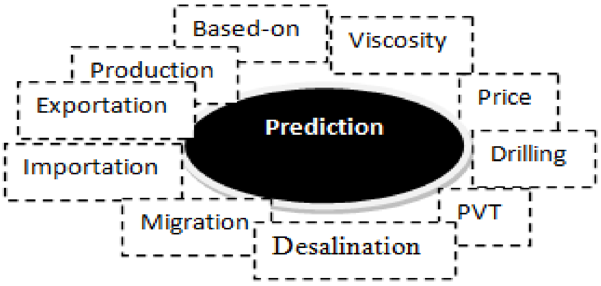
Prediction of crude oil returns is an important issue in oil industry. Because prediction is incomplete, uncertain and vague, that makes it a challenge to predict of the future performance. Accurate predictions of crude oil presence are important for many reasons; neural networks can’t be used to explain the casual relationships between input and output variables. This is because of the essentially black box like nature of many existing neural network architectures [4]. The fuzzy approach has been applied to different forecasting problems whereby the operator’s expert knowledge is used for prediction [5]. The combination of artificial neural network with fuzzy method can create an efficient approach for various modelling systems, so that each of these two methods may recover the weakness of another and increase the efficiency of the neuro-fuzzy system [6]. Neuro-fuzzy has been used in crude oil prediction during the last decade. Recent research in the area of neuro-fuzzy systems has shown that fuzzy logic and neural networks shows the properties required for relevant applications such as non-linear, ability to learn complex non linear mappings, prove membership functions and fuzzy rules, and self-adaptation for different statistical distributions. Neuro-fuzzy modeling refers to the way of applying various learning techniques developed in the neural network literature to fuzzy modeling or a fuzzy inference system (FIS) [7].

ANFIS methodology interprets more than one process between input and output. Processes are fuzzification (comprises the process of transforming crisp values into grades of membership for linguistic terms of fuzzy sets.), inference (formulating the mapping from a given input to an output) and defuzzification (producing a quantifiable result) [8]. ANFIS networks have been successfully applied to classification tasks, rule-based process controls, pattern recognition problems and the like [9]. Fuzzy control algorithms and especially ANFIS have been widely applied to predict process, on the other hand, they use a non-linear approach to create a model, so when encountered with the complicated and non-linear data, these networks may express such a data much more accurately as a defined model [10]. One of the neuro-fuzzy systems in which learning algorithm is coincided with integrates approaches is ANFIS system. In recent years, many investigations have been performed to apply the ANFIS system for modelling of the engineering.

The rest of the paper is organized as follows: A brief description about problem and different related searches are provided in section 2. Then, section 3 explains petroleum and ANFIS description, experimental process displayed too. Section 4, shows the application results evaluation steps. Section 5, concludes this paper with a brief summary and some suggestions for searches future work.

2. Related Work

Fundamentally, neural fuzzy modeling is the task of building models from a combination of a priori knowledge and empirical data from distinct sources. Normally, such a priori knowledge is used to define a suitable model structure. The main objective of neural fuzzy modeling is to construct a model that accurately predicts the value(s) of the output variable(s) when new values of the input variables are presented [11]. There are many searches which are concern of prediction process [12]. Crude oil prediction domain has been many searches on different fields such as viscosity, production and other, as shown at fig (1).



Fig(1). Fields of crude oil searches

This work depends on the recently related work which explains an application of neural network to predict gas and oil ratio within crude oil [13].

Petroleum fluids, which include gas condensates, absorber oils, petroleum crude and heavy oil, are in the category of complex mixtures [14]. In petroleum Fluid mixtures there could exist various families of hydrocarbons (paraffins, aromatics, naphtenes, etc). This verity of crude oil properties diversity proves and explains that the crude oil prediction process complex.

Obviously, petroleum prediction methods are: (1) by analogy,(2) volumetrics,(3) material balance,(4) decline curve fitting, and(5) reservoir simulation (Thompson and Wright,1985). Although these methods have its strengths and weaknesses, the methods have different data requirements [15]. There are advantages of neural networks include its computational efficiency, nonlinear characteristics, generation properties, and ease of working with high dimensional data [16]. On other hand, ANFIS has the ability for training and testing the dataset, prove better accuracy test and less percentage of errors. Applying backpropagation function on ANFIS doesn't achieve the best accuracy result, goal of this work [17].

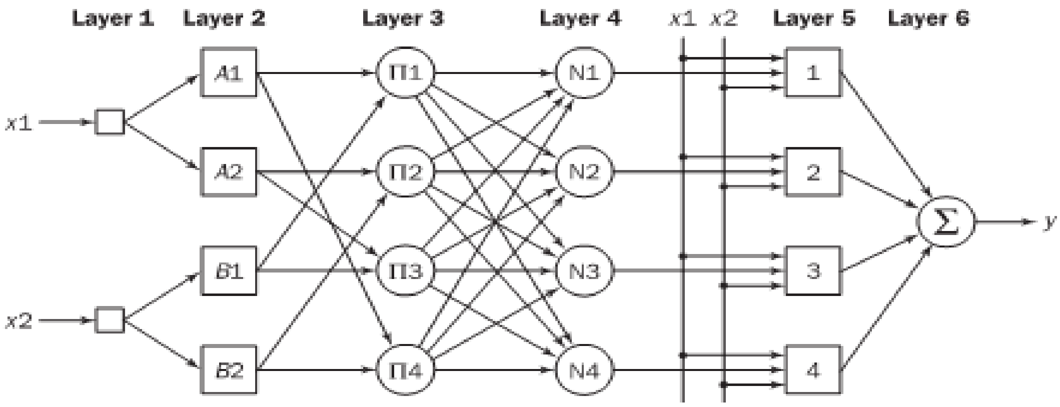
3. Petroleum and ANFIS

Petroleum processing within ANFIS represented through many steps which are: (a) load crude oil data training, (b) represent crude oil dataset as input, (c) fuzzification process; shows how the dataset divided into sets, take the crisp inputs, x and y and determine the degree to which these inputs belong to each of the appropriate fuzzy sets. The crisp input is always a numerical value limited to the universe of discourse. Rule evaluation and aggregation are other steps of fuzzification process. (d) inference process; a process of training knowledge to produce the output, using the theory of fuzzy sets, (e) defuzzification process; evaluate the rules, but the final output of a fuzzy system has to be a crisp number. The input for the defuzzification process is the aggregate output fuzzy set and the output is a single number.

There are two famous methods on fuzzy systems which are sugeno and mamdani; the first method is more usage whereas mamdani is not computationally effective. The format of the Sugeno-style fuzzy rule is: IF x is A AND y is B THEN z is f (x, y) [18]. The most commonly used zero-order Sugeno fuzzy model applies fuzzy rules in the following form: IF x is A AND y is B THEN z is k where k is a constant [19]. The basic objectives of neural fuzzy modeling are: Predictability which aims to construct a model from observed data, Interpretability which is representation of the extracted knowledge , Efficiency for application resources and Adaptability which defined by The ability to adapt and learn from the patterns of data that were not present in the original training and testing sets [20].

Sugeno method on ANFIS is better for computing calculation [21]. The basic layers of ANFIS as intelligent technique with sugeno model used [22, 23]. The Sugeno fuzzy model was proposed for a systematic approach to generating fuzzy rules from a given input-output dataset. Atypical Sugeno fuzzy rule can be expressed in the following form:

IF x_1 is A_1 AND x_2 is A_2.....AND x_m is A_m THEN $y = \mathcal{F}(x_1; x_2; ... ; x_m)$, where x1; x2; ... ; xm are input variables; A1;A2; ... ;Am are fuzzy sets; and y is either a constant or a linear function of the input variables. Figure (2) explain using of ANFIS methodology, using six layers as sugeno method.



Fig(2). Adaptive Neuro-Fuzzy Inference

While Layer1 is the input layer, neurons in this layer simply pass external crisp signals to Layer2. Layer2 is the fuzzifica Fig(2). Crude oil application using ANFIS ayer4 is the normalization layer; Layer5 is the defuzzification layer and Layer6 is represented by a single summation neuron.

ANFIS implements four rule:

Rule 1: IF x1 is A1 AND x2 is B1 Then $y = f_1 = K_{10} + K_{11}x1 + k_{12}x2$

Rule 2: IF x1 is A2 AND x2 is B2 Then $y = f_2 = K_{20} + K_{21}x1 + k_{22}x2$

Rule 3: IF x1 is A2 AND x2 is B1 Then $y = f_3 = K_{30} + K_{31}x1 + k_{32}x2$

Rule 4: IF x1 is A1 AND x2 is B2 Then $y = f_4 = K_{40} + K_{41}x1 + k_{42}x2$

Where x1, x2 are input variables; A1and A2 are fuzzy sets on the universe of discourse X1; B1and B2 are fuzzy sets on the universe of discourse X2;and k_{i0}, k_{i1} and k_{i2} is a set of parameters specified for rule i.

3.1 Experimental Results

ANFIS architecture that correspond the first order Sugeno fuzzy model. For simplicity, ANFIS has two inputs x1 and x2 and one output y. ANFIS functions which are used prediction applications concern of parameters and vector, some of these functions which are used on oil and gas ration prediction from crude oil data are:

$$f(x,a,b,c) = \max\left(\min\left(\frac{x-a}{b-a},\frac{c-x}{c-b}\right),o\right) \quad (1)$$

The parameters on every function such curves plotted for the values of the vector x, a,b,c and d locate on curve sides.

$$f(x,a,b,c,d) = \max\left(\min\left(\frac{x-a}{b-a},\frac{d-x}{d-c}\right),o\right) \quad (2)$$

This function differ than the last one on parameters positions on the curve, where some locate on the “feet”, other locate on the “shoulders” of the curve.

$$f(x,a,b,c) = \frac{1}{1+\left|\frac{x-c}{a}\right|^{2b}} \quad (3)$$

Hence, at all functions, each input is represented by two fuzzy set and the output by a first order polynomial. Conveniently, it is not necessary to have any prior knowledge of rule consequent parameters for an ANFIS to deal with a problem. An ANFIS learns these parameters and membership functions.

$$f(x,\sigma,c) = e\,\frac{-(x-c)^2}{2\sigma^2} \quad (4)$$

The parameters on this function represent the parameters σ and c listed in order in the vector x.

$$f(x,a,c) = \frac{1}{1+e^{-(x-c)}} \quad (5)$$

$$f(x;a,c) = \frac{1}{1+e^{-a(x-c)}} \quad (6)$$

Test the crude oil data of thirty wells by using ANFIS functions. The dataset which are training are the same dataset which are proven with different intelligent computing techniques. Related search train the data for five wells only, whereas in this search training the dataset for thirty wells. The same crude oil dataset are applied through two intelligent computing techniques which are BP and FNN. Development accurate predictive compositional models, it is necessary to have many experimental data. For this reason, a crude oil database is proposed, the dataset including crude oil properties on 30 well mining from Daqing oilfield. Applying ANFIS functions on that crude oil dataset produce better result than other techniques.

Exploiting fuzzy neural network to predict crude oil based on measured value of crude oil properties of thirty exploratory wells in Daqing oilfield. From that crude oil dataset properties, the ability of ANFIS functions to training and testing the dataset produce more accurate results on oil and gas volume ratio prediction. Prediction process not only on crude oil domain, but on different domains still complex scientifically because loss of data during training and testing processes. Percentage of accurately process is the important step on prediction process. The key for prediction is to choose an appropriate network structure and related parameters.

The four main factors on the application are: pressure, temperature, crude oil density, surface crude oil gravity. The node number on input layer is four whereas the node number on the output layer is 1. By applying these data on ANFIS functions to predicting volume of oil and gas ratio depending on Daqing oilfield dataset, the result which produced through ANFIS are better than the result which approved by other intelligent computing technique (BP, FNN).

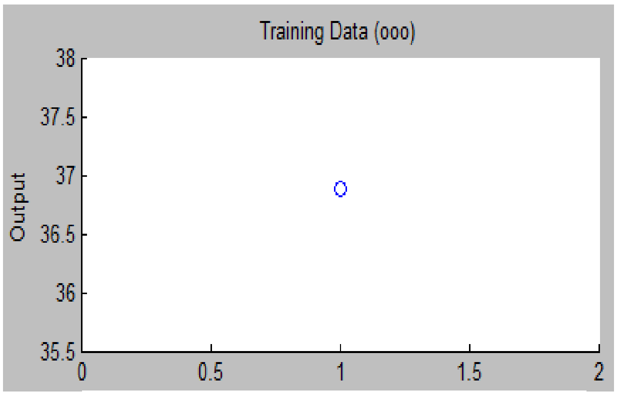
Table (1). Prediction result compared with related

Result of related prediction paper (**BP, FNN**)						**ANFIS**-based Prediction result	
Well Sample	**Measured Value**	**Prediction Value By BP**	**Error (%)**	**Prediction Value By FNN**	**Error (%)**	**Prediction Value By ANFIS**	**Error (%)**
25	36.88	33.75	8.49	34.18	7.32	**36.85**	**3.98**
26	12.50	11.52	7.84	11.95	4.4	**12.46**	**1.495**
27	17.83	16.16	9.37	16.83	5.61	**17.78**	**1.805**
28	12.92	11.78	8.82	12.02	6.97	**12.89**	**1.42**
29	17.27	15.33	11.84	16.19	6.25	**17.20**	**1.732**
30	13.73	11.84	13.77	12.42	9.54	**13.70**	**2.8**

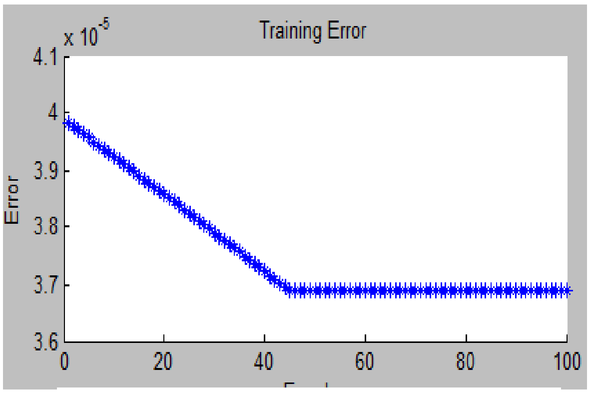
The results shown above shows that prediction values by ANFIS technique are better than other results of measured values and errors percentage which are proven by BP and FNN. On other hand, the results ANFIS predictions values closer to measured values than other techniques. Conceptually, implementation of thirty well dataset on Daqing oil field shows that using of training and testing processes many times produce the error percentage. On case of well 25 the training process repeated many times started at 6.2, the training process within 100 epochs produce the minimum error percentage at 3.98%. On other hand, measured value of prediction on BP technique is 33.74, error percentage is 8.49%, that's mean clearly ANFIS result distinguish about other intelligent techniques results.

4. Application Evaluation

The application presented here is an initial attempt to predict the behavior of such oil and gas volume ration of input data necessary. To evaluate oil and gas prediction from crude oil data of Daqing oilfield within 30 well dataset by Matlap, well 25 choose as a sample to test. The result of measured values and error percentage prediction shown on figures 4(a,b), whereas figure5(c,d), represents measured value and error percentage for 30 wells of Daqing oilfield. There are two methods of training process which are data training and error training. The training processes are applied for crude oil dataset on Daqing oil field, the results of these processes shown on figures (4,5). During training process for crude oil dataset there are close and exact results for empirical results. On other hand, through error training process, it shows that processes repeated more than one time, the minimum result which is closer than zero, means that it is the best result than other. Epochs values detected within 100, to illustrate the minimum percentage of error, simultaneously, it applied for all 30 wells, the last six wells are selected, to compare ANFIS prediction results with BP and FNN on the same wells.

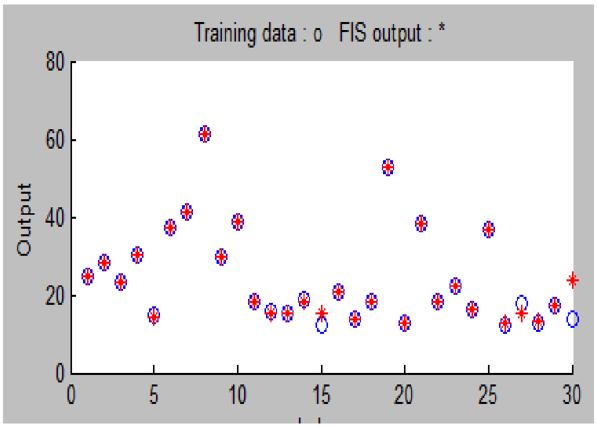


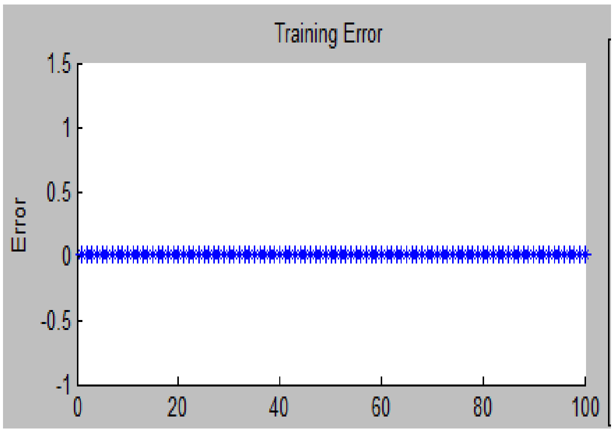
a . Oil and Gas measured value (well 25)



b. Oil and Gas error percentage (well 25)

Figure (4).Oil and Gas measured value and error percentage of well 25 as a sample, hence, output value (36.85) closer to empirical measured value, on other hand, the error percentage (3.98) less than other techniques values.





d . Oil and Gas error percentage of 30 wells   c . Oil and Gas measured value of 30 wells

Figure (5).Oil and Gas measured value and error percentage of 30 wells on Daqing oilfield. The output values closer to empirical measured value (c), there are sequentially output close for empirical data. On other hand, training and testing processes for error percentage at "0" (d) whereas, training the same data by BP and FNN is 0.0318. Hence, ANFIS results as oil and gas measured values and errors percentage is less than other intelligent computing techniques (BP and FNN) values which are applied with the same dataset of Daqing oilfield.

5. Conclusion and Future Work

During the past decade, many searches has been made in the develop applications for estimating future prediction of petroleum fields. However, these applications are usually either difficult to use or inaccurate. The neural network techniques are widely usage on petroleum prediction field. This work exploits the dataset of 30 wells on Daqing oilfield using ANFIS technique; obviously, ANFIS results of oil and gas volume ratio prediction are better than results(measured value and error percentage) of BP and FNN and more accurate. On future work, using other techniques and functions are still desired for develop petroleum prediction domain and achieve more accurate results.

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