Asian Journal of Information Technology 1 (1): CCCC, 2008
ISSN: 1682-3915

Well Logs Analysis Using Neuro-Fuzzy Technology (Case Study of Niger-Delta Region of Nigeria)

[1]A.B. Adeyemo, [2]O.C. Akinyokun and [3]A. Adesida
[1]Department of Computer Science, University of Ibadan, Ibadan, Nigeria
[2]Department of Computer Science, [3]Department of Applied Geophysics,
Federal University of Technology, Akure, Nigeria

Abstract: Petrophysical log interpretation is one of the most useful and important tools available to a petroleum geologist. Well logs help to define physical rock characteristics such as lithology, porosity, permeability and to identify productive zones, to determine depth and thickness of zones, to distinguish between oil, gas, or water in a reservoir and to estimate hydrocarbon reserves. This study presents the results of a study that used unsupervised Self Organizing Map (SOM) artificial neural networks and fuzzy rules derived from log characteristics for the determination of oil well lithology from open-hole geophysical well logs. The methodology proposed for the identification of oil well lithology was tested with case data obtained from an oil well located in the Niger delta region of Nigeria. The result shows that the fuzzy logic based log interpretation model used for the analysis of the clusters (log-facies) generated from the well logs can be used to identify and classify the lithology of oil wells without the use of core sample data.

Key words: Log facies, SOM neural networks, fuzzy logic, Niger-delta region

INTRODUCTION

Artificial Neural Networks are non-linear, sophisticated modeling techniques capable of modeling extremely complex functions (Statsoft, 2002). Artificial Neural Networks can transform a linearly inseparable problem into a linearly separable one. They learn by example and can be applied in virtually every situation in which a relationship between the predictor variables (independents, inputs) and predicted variables (dependents, outputs) exists. They are applicable even when the relationship may be very complex and not easy to articulate in the usual terms of "correlations" or differences between groups.

Artificial Neural Networks can be trained using either the supervised or the unsupervised learning or training techniques (Statsoft, 2002). In supervised learning, the correct results (target values, desired outputs) are known and are given to the network during training. The network can adjust its weights to match its outputs to the target values and the network learns to infer the relationship between the two. Training data is usually taken from historical records. The network is trained using one of the supervised learning algorithms of which the best-known example is the back propagation method.

Artificial Neural Networks that use the unsupervised learning paradigms are very simple, one-layer networks. In unsupervised learning there is no teacher and the network must self-organize according to some internal rules in response to the environment. A number of unsupervised learning algorithms exist. Some of these are the Hebbian and the Competitive learning methods (Statsoft, 2002). The Hebbian learning is the most common variety of unsupervised learning. The Oja's and Sangers unsupervised learning are variants of plain Hebbian learning that can be used for principal component analysis. The Sanger's learning procedure can also extract the principal components with respect to the output unit ordering.

The Kohonen Self-Organizing (feature) Map (SOM) network (Kohonen, 1995) uses the competitive learning method. The SOM network has only two layers of processing elements (or neurons). These are the input layer and an output layer of radial units (also known as the topological map layer). The units in the topological map layer are laid out in space, usually in two dimensions. The SOM artificial neural network which combines competitive learning with dimensionality reduction can be used for exploratory data analysis, classification tasks and novelty detection.

Corresponding Author: A.B. Adeyemo, Department of Computer Science, University of Ibadan, Ibadan, Nigeria

The basic theory of fuzzy sets was first introduced by Zadeh (1965). Unlike classical logic, which is based on crisp sets of "true and false", fuzzy logic views problems as a degree of "truth", or "fuzzy sets of true and false". It is a methodology that was developed to obtain an approximate solution where the problems are subject to vague description. The major concept of fuzzy logic is the use of a linguistic variable which is a variable whose values are words or sentences in a natural or synthetic language. This also leads to the use of fuzzy if-then rules, in which the antecedent and consequents are propositions containing linguistic variables.

Neuro-fuzzy modeling is a technique for describing the behavior of a system using fuzzy inference rules within a neural network structure. The model has a unique feature in that it can express linguistically the characteristics of a complex nonlinear system. In recent years, fuzzy logic, or more generally, fuzzy set theory, has been applied extensively in many reservoir characterization studies (Nikravesh and Aminzadeh, 2002). This is mainly due to the fact that reservoir geology is mainly a descriptive science which uses mostly uncertain, imprecise, ambiguous and linguistic information. Fuzzy set theory has the ability to deal with such information and to combine them with the quantitative observations.

The prediction of lithofacies (that is, rock type identification) is important for many geological and engineering disciplines. The conventional method used for the identification of lithofacies is by direct observation of underground cores (Chang *et al*., 2002). These are small cylindrical rock samples, retrieved from oil wells at selected well depths. The recovery of cores is an expensive process and is not always total. In addition, different geologists may provide different interpretations for the retrieved core samples. This is why a lower-cost method providing similar or higher accuracy is desirable (Chang *et al*., 2002). In an attempt to solve such reservoir characterization problems using differed well logging measurements, some researchers in geosciences have employed statistical methods and the use of artificial neural networks. Some published research using some of these techniques to solve reservoir characterization and lithology determination or prediction problems include: Soto and Holditch (1999), Mohaghegh (2000), Chang *et al.* (2000), Ford and Kelly (2001), Barlai (2002) and Chikhi *et al.* (2004). Most of the researches used supervised neural networks trained with core samples to recognize rock types present in a fresh data set previously unseen by the neural network. Chang *et al.* (2002) reported the use of an unsupervised SOM network to generate clusters in log data and used classified core data for the lithology identification program.

From studies of well log characteristics the well logs that can be used for lithology determination are Gamma Ray (GR) log, Density (DEN) log, Neutron (NEU) log, Electrical Resistivity (RES) log. Gamma ray logs measure natural radioactivity in formations. Shale-free sandstones and carbonates give low gamma ray readings. As shale content increases, the gamma ray log response also increases. The resistivity log is a measure of a formation’s resistivity. Most rock materials are essentially insulators, while their enclosed fluids are conductors. When a formation is porous and contains salty water, the overall resistivity will be low. When this same formation contains hydrocarbons, its resistivity will be very high. Shales show low resistivity values with high gamma ray values. The density log is a continuous record of a formation’s bulk density. It is used mainly for the determination of porosity and the differentiation between liquids and gases (when used in combination with neutron log). When organic content is present, density is low. Variation of density indicates porosity changes. For example, low density indicates high porosity and vice-versa. On cross-plot of neutron and density logs, pure shale can be recognized by the high neutron value relative to the density value which gives a large positive separation to the logs while gas stands out distinctly giving a large negative separation.

This study presents the result of a study that proposed a methodology for the identification and classification of oil well lithology and fluid content using a SOM neural network to generate log-facies or electro-facies (Rider, 1996) from geophysical well logs and fuzzy rules generated from the known physical properties of the well logs. With the fuzzy rules the lithology of the wells can be determined without the use of core sample data. A case study program was implemented using case data from the Niger Delta region of Nigeria. The Niger Delta is situated in the Gulf of Guinea and extends throughout the Niger Delta Province. It contains only one identified petroleum system referred to as the Tertiary Niger Delta (Akata-Agbada) Petroleum System (Tuttle *et al*., 1999). It is composed of mainly sedimentary rock and divided into three formations. These are Benin formation, Agbada formation and Akata formation. The Benin formation consists of mainly sand, the Agbada formation consists of sand and shale, while the Akata formation consists of shale. Limestone and salts are not found in the Niger Delta region. The depth of the Benin formation is about 6,000 ft, the Agbada formation about 17,000 ft and Akata formation about 6,000 ft. The source rocks for the petroleum system are located in the Akata formation while the petroleum reservoirs are located in the Agabda formation.

MATERIALS AND METHODS

The base data used for the lithology determination are the open-hole wireline subsurface well log data. Cross-plot techniques are employed in the analysis of well log data. The log data models the response of the subsurface rocks to the measuring instrument according to the rock properties. The cross-plots allow the nature of the rocks properties to be inferred from the logs. However, due to visualization problems, the cross-plots cannot handle more than 3-dimensional data. It was observed that the operation of the SOM based clustering algorithm is similar to plotting a multi-dimensional log cross-plot. It is noted that in the conventional cross-plot chart, if the dimensions of the chart are more than three dimensions, the visualization and interpretation of the cross-plot chart becomes more complex. The SOM based clustering algorithm has the advantage of not being limited to three dimensions.

The analysis of the well logs begins by first cleaning the log data. Erroneous data items and outliers were removed from the raw well log data. A correlation test was performed on the log values to determine if there was any relationship between the log data values. Knowing the nature of the relationships also helps in the selection of the appropriate log variables when similar data items are present in the data records. The data elements were normalized (between the range 0 and 1) to renders the input data dimensionless and remove the effect of scaling. The neural network was then trained using a training data set.

After training the SOM, the neural network would have learned the structure of the input data. The testing data file, which contains the data that is to be clustered, is now submitted to the trained SOM network, which then identifies the clusters it has recognized during the training process. The test data file may be the same as the training data file or any other data file, which is to be classified, based on the clusters identified by the training data set. The data samples are assigned to cluster groups by the SOM software and the result saved in either a spreadsheet file or an ASCII text file. Each data sample is assigned a label (number) showing the cluster to which it has been assigned. The output file is imported into a spreadsheet file, sorted to group data samples belonging to the same clusters together and then the mean and standard deviation of each cluster group computed.

The computed mean of the log values were used to infer the lithology and fluid content of the rock species that characterize the geological formation of the oil well being investigated by determining their fuzzy value. In a fuzzy system, the general inference process proceeds in the following steps.

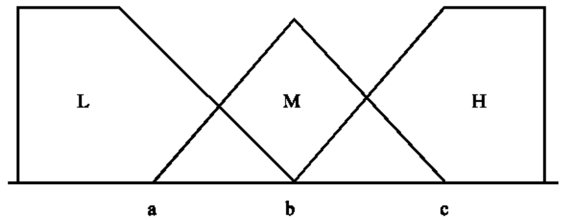

Fig. 1: Fuzzy membership functions

- Fuzzification which involves the conversion of numeric data in real world domain to fuzzy numbers in fuzzy domain.
- Fuzzy inference which involves the computation of the truth value of each rule and its application to the conclusion part of the rule.
- Composition of the output variables of sub rules which can fire in parallel for the purpose of drawing a global conclusion.
- Deffuzzification, which is optional, involves the conversion of the derived fuzzy number to the numeric data in real world domain.

The fuzzy value of the logs can be modeled by four fuzzy membership functions which correspond to the linguistic values High (H), Moderate (M), or Low (L) as shown in Fig. 1.

The fuzzy values are used to generate fuzzy rules for the identification of rock lithologies represented by log data clusters generated by the SOM software. Mathematically this can be represented by Eq. 1 as:

$$x_j = \begin{cases} H \text{ if } b \geq x \leq c \\ M \text{ if } a > x < b \\ L \text{ if } x \leq a \end{cases} \quad (1)$$

Where,

x_j represents mean value of subset j (of log reading)
a, b and c represents threshold values

In determining, the threshold value a, b and c used in this work the following were noted:

- The gamma ray log value in shales varies enormously in any one area or well and it ranges between 40 and 112 API and in sandstones ranges between 10 and 50 API (Rider, 1996). The threshold values used for the Gamma Ray log (GR) are:

  a = 40 API, b = 50 API, c = 112 API

- There are no characteristic resistivity limits for shales, limestone and sandstone (Rider, 1996).

However, it is noted that resistivity values are low for shales, sandstone and water. It is high for hydrocarbons (oil/gas). The threshold values used for the un-invaded resistivity log (RES) are:

a = 10 ohm-m, b = 100 ohm-m, c = 300 ohm-m

- In shales the density log value ranges between 1.18 and 2.75 g cm^{-3}, while in sandstones it ranges between 1.9 and 2.65 g cm^{-3}. Since oilfield densities are usually between 2.0 and 3.0 g cm^{-3} and the mean apparent dry bulk density for shales is 2.45 g cm^{-3} (Rider, 1996). The threshold values used for the Density (DEN) log are:

a = 2.45 g cm^{-3}, b = 2.65 g cm^{-3}, c = 3.0 g cm^{-3}

In order to generate the fuzzy rules to be used for the analysis of the clusters a rock properties determination matrix was created using the known log properties. Using three fuzzy membership functions and three logs gave 27 unique combinations. Not all the rules are physically feasible. However, since the known primary lithology is sand and shale, this provides a way for reducing the number of rules generated to a more manageable and effective number by selecting only the rules relevant to the objective of the study. These are the rules for determining the well lithology which is classified as being shale, sandy-shale, pay sand and wet sand. The relevant combinations are presented in Table 1. In deriving the rules, the following were considered:

- The gamma ray log, which is the primary lithology log, was used to determine the primary lithology of the rock type.
- Next, the resistivity log was used to determine if there is any hydrocarbon presence indicated by a high resistivity log value.
- Finally, the density log was used to further characterize the lithofacies.

The fuzzy rules inferred from the rules determination matrix are:

1. If (GR = H) and (RES = L) and (DEN = H or M)
   Then (Lithology = Shale)
2. (GR = L) and (RES = L) and (DEN = H or M)
   Then (Lithology = Sandy-shale)
3. If (GR = L) and (RES = H) and (DEN = M)
   Then (Lithology = Pay Sand)
4. If (GR = L) and (RES = H) and (DEN = L)
   Then (Lithology = Pay Sand)
5. If (GR = L) and (RES = M) and (DEN = M)
   Then (Lithology = Pay Sand)
6. If (GR = L) and (RES = M) and (DEN = L)
   Then (Lithology = Pay Sand)
7. If (GR = L) and (RES = L) and (DEN = L)
   Then (Lithology = Wet sand)

RESULTS AND DISCUSSION

Case studies using well log data from the Niger Delta region of Nigeria (obtained from Shell Petroleum Development Corporation with the permission of the Department of Petroleum Resources, Nigeria) were carried out. The log data contains the Depth (DEP), the True Vertical Depth (TVD), Gamma Ray log (GR), Resistivity log (RES) and Density log (DEN). The log had 3941 data elements which ranged from 7000-11870 ft. A correlation test was carried out on the input data. The result showed that the Depth (DEP) and True Vertical Depth (TVD) were highly correlated hence, only the Depth (DEP) values were used. The well logs were then normalized. The data was then used to train the SOM software and clusters were generated. The mean log value

Table 1: Fuzzy rules determination matrix

	GR value	RES value	DEN value	Indicated lithology
1	H or M	L	H or M	Shale
2	L	L	H or M	Sandy-shale
3	L	H	M	Pay sand
4	L	H	L	Pay sand
5	L	M	M	Pay sand
5	L	M	L	Pay sand
6	L	L	L	Wet sands

Table 2: Clusters generated by SOM software

Cluster	No. of samples		GR	RES	DEN
1	18	Mean	33.01778	493.666668	2.375
		SD	3.345639	120.187046	0.025029394
2	3	Mean	40.89333	567.64331	2.33666667
		SD	1.247812	4.1311504	0.04163332
3	56	Mean	35.73875	91.053929	2.43821429
		SD	3.162037	54.191674	0.02249098
4	599	Mean	85.81002	21.328431	2.53435726
		SD	22.72294	27.803078	0.04879703
5	6	Mean	39.42667	1441.0467	2.30666667
		SD	1.456896	250.23838	0.01966384
6	92	Mean	32.23467	5.61130435	2.428695652
		SD	4.573356	0.5782566	0.022833241
7	64	Mean	36.40203	49.0335937	2.41921875
		SD	3.837196	30.0236259	0.046369965
8	94	Mean	34.19521	225.854576	2.372765957
		SD	3.162344	88.2995406	0.029924789
9	162	Mean	91.79079	18.2691089	2.499517327
		SD	28.73966	35.3942291	0.082534254
10	578	Mean	114.4018	4.80583045	2.621557093
		SD	12.52467	1.71185725	0.040848849
11	3	Mean	34.08	54.753334	2.406666667
		SD	3.016768	6.50432495	0.015275252
12	812	Mean	104.117	9.53756159	2.483054187
		SD	24.15951	10.3751173	0.044311775

DEP		DEP		DEP		DEP		DEP		DEP		DEP		DEP		DEP		DEP		DEP		DEP	
9900	9	9955	9	10010	9	10065	9	10120	9	10175	9	10230	9	10285	9	10340	9	10395	9	10450	9	10505	6
9901	9	9955.5	9	10011	9	10066	9	10121	9	10176	9	10231	9	10286	9	10341	9	10396	9	10451	9	10506	6
9901	9	9956	9	10011	9	10066	9	10121	9	10176	9	10231	9	10286	9	10341	9	10396	9	10451	9	10506	6
9902	9	9956.5	9	10012	9	10067	9	10122	9	10177	9	10232	9	10287	9	10342	9	10397	9	10452	9	10507	6
9902	9	9957	9	10012	9	10067	9	10122	9	10177	9	10232	9	10287	9	10342	9	10397	9	10452	9	10507	6
9903	9	9957.5	9	10013	9	10068	9	10123	9	10178	9	10233	9	10288	9	10343	9	10398	9	10453	9	10508	9
9903	9	9958	9	10013	9	10068	9	10123	9	10178	9	10233	9	10288	9	10343	9	10398	9	10453	9	10508	9
9904	9	9958.5	9	10014	9	10069	2	10124	9	10179	9	10234	9	10289	9	10344	9	10399	9	10454	9	10509	6
9904	9	9959	9	10014	9	10069	5	10124	9	10179	9	10234	9	10289	9	10344	9	10399	9	10454	9	10509	6
9905	9	9959.5	9	10015	9	10070	5	10125	9	10180	9	10235	9	10290	9	10345	9	10400	9	10455	9	10510	6
9905	9	9960	9	10015	9	10070	5	10125	9	10180	9	10235	9	10290	9	10345	9	10400	9	10455	9	10510	6
9906	9	9960.5	9	10016	9	10071	5	10126	9	10181	9	10236	9	10291	9	10346	9	10401	9	10456	9	10511	6
9906	9	9961	9	10016	9	10071	5	10126	9	10181	9	10236	9	10291	9	10346	9	10401	9	10456	7	10511	6
9907	9	9961.5	9	10017	9	10072	5	10127	9	10182	9	10237	9	10292	9	10347	9	10402	9	10457	7	10512	6
9907	9	9962	9	10017	9	10072	1	10127	9	10182	9	10237	9	10292	9	10347	9	10402	9	10457	9	10512	6
9908	9	9962.5	9	10018	9	10073	1	10128	9	10183	9	10238	9	10293	9	10348	9	10403	9	10458	9	10513	6
9908	9	9963	9	10018	9	10073	8	10128	9	10183	9	10238	9	10293	9	10348	9	10403	9	10458	9	10513	6
9909	9	9963.5	9	10019	9	10074	8	10129	9	10184	9	10239	9	10294	9	10349	9	10404	9	10459	9	10514	6
9909	9	9964	9	10019	9	10074	2	10129	9	10184	9	10239	9	10294	9	10349	9	10404	9	10459	9	10514	6
9910	9	9964.5	9	10020	9	10075	1	10130	9	10185	9	10240	9	10295	9	10350	9	10405	8	10460	9	10515	6
9910	9	9965	9	10020	9	10075	1	10130	9	10185	9	10240	9	10295	9	10350	9	10405	8	10460	9	10515	6
9911	9	9965.5	9	10021	9	10076	2	10131	9	10186	9	10241	9	10296	9	10351	9	10406	8	10461	9	10516	6
9911	9	9966	9	10021	9	10076	9	10131	9	10186	9	10241	9	10296	9	10351	9	10406	8	10461	9	10516	6
9912	9	9966.5	9	10022	9	10077	9	10132	9	10187	9	10242	9	10297	9	10352	9	10407	7	10462	9	10517	6
9912	9	9967	9	10022	9	10077	9	10132	9	10187	9	10242	9	10297	9	10352	9	10407	7	10462	9	10517	6
9913	9	9967.5	9	10023	9	10078	9	10133	9	10188	9	10243	9	10298	9	10353	9	10408	9	10463	9	10518	6
9913	9	9968	9	10023	9	10078	9	10133	9	10188	9	10243	9	10298	9	10353	9	10408	9	10463	9	10518	6
9914	9	9968.5	9	10024	9	10079	8	10134	9	10189	9	10244	7	10299	9	10354	9	10409	9	10464	9	10519	6
9914	9	9969	9	10024	9	10079	9	10134	9	10189	9	10244	7	10299	9	10354	9	10409	9	10464	9	10519	6
9915	9	9969.5	9	10025	9	10080	9	10135	9	10190	9	10245	7	10300	9	10355	9	10410	9	10465	9	10520	6
9915	9	9970	9	10025	9	10080	9	10135	9	10190	9	10245	9	10300	9	10355	9	10410	9	10465	9	10520	6
9916	9	9970.5	9	10026	9	10081	9	10136	9	10191	9	10246	7	10301	9	10356	9	10411	9	10466	9	10521	6
9916	9	9971	9	10026	9	10081	9	10136	9	10191	9	10246	7	10301	9	10356	9	10411	9	10466	9	10521	6
9917	9	9971.5	9	10027	9	10082	9	10137	9	10192	9	10247	7	10302	9	10357	9	10412	8	10467	9	10522	6
9917	9	9972	9	10027	9	10082	9	10137	9	10192	9	10247	7	10302	9	10357	9	10412	8	10467	9	10522	6
9918	9	9972.5	9	10028	9	10083	9	10138	9	10193	9	10248	7	10303	9	10358	9	10413	8	10468	9	10523	6
9918	9	9973	9	10028	9	10083	9	10138	9	10193	9	10248	7	10303	9	10358	9	10413	8	10468	9	10523	6
9919	9	9973.5	9	10029	9	10084	9	10139	9	10194	9	10249	7	10304	9	10359	9	10414	8	10469	9	10524	6
9919	9	9974	9	10029	9	10084	9	10139	9	10194	9	10249	7	10304	9	10359	9	10414	8	10469	9	10524	6
9920	9	9974.5	9	10030	9	10085	9	10140	9	10195	9	10250	7	10305	9	10360	9	10415	8	10470	9	10525	6
9920	9	9975	9	10030	9	10085	9	10140	9	10195	9	10250	7	10305	9	10360	9	10415	7	10470	9	10525	6
9921	9	9975.5	9	10031	9	10086	9	10141	9	10196	9	10251	7	10306	9	10361	7	10416	7	10471	9	10526	6
9921	9	9976	9	10031	9	10086	9	10141	9	10196	9	10251	7	10306	9	10361	7	10416	9	10471	9	10526	6
9922	9	9976.5	9	10032	9	10087	9	10142	9	10197	9	10252	7	10307	9	10362	9	10417	9	10472	9	10527	6
9922	9	9977	9	10032	9	10087	9	10142	9	10197	9	10252	9	10307	9	10362	9	10417	9	10472	9	10527	6
9923	9	9977.5	9	10033	9	10088	9	10143	9	10198	9	10253	7	10308	9	10363	8	10418	9	10473	9	10528	6
9923	9	9978	9	10033	9	10088	9	10143	9	10198	9	10253	7	10308	9	10363	8	10418	9	10473	9	10528	6
9924	9	9978.5	9	10034	9	10089	9	10144	9	10199	9	10254	7	10309	9	10364	8	10419	9	10474	9	10529	6
9924	9	9979	9	10034	9	10089	9	10144	9	10199	9	10254	9	10309	9	10364	8	10419	8	10474	9	10529	6
9925	9	9979.5	9	10035	9	10090	9	10145	9	10200	9	10255	9	10310	9	10365	8	10420	8	10475	9	10530	6
9925	9	9980	9	10035	9	10090	9	10145	7	10200	9	10255	9	10310	9	10365	8	10420	8	10475	9	10530	6
9926	9	9980.5	9	10036	9	10091	9	10146	7	10201	9	10256	9	10311	9	10366	8	10421	8	10476	9	10531	6
9926	9	9981	9	10036	9	10091	9	10146	7	10201	9	10256	9	10311	9	10366	8	10421	8	10476	9	10531	6
9927	9	9981.5	9	10037	9	10092	9	10147	7	10202	9	10257	9	10312	9	10367	8	10422	8	10477	9	10532	6
9927	9	9982	9	10037	9	10092	9	10147	7	10202	9	10257	9	10312	9	10367	8	10422	9	10477	9	10532	6
9928	9	9982.5	9	10038	9	10093	9	10148	8	10203	9	10258	9	10313	9	10368	8	10423	9	10478	9	10533	6
9928	9	9983	9	10038	9	10093	9	10148	8	10203	9	10258	9	10313	9	10368	8	10423	9	10478	9	10533	6
9929	9	9983.5	9	10039	9	10094	9	10149	8	10204	9	10259	9	10314	9	10369	8	10424	9	10479	9	10534	6
9929	9	9984	9	10039	9	10094	9	10149	8	10204	9	10259	9	10314	9	10369	1	10424	9	10479	9	10534	6
9930	9	9984.5	9	10040	9	10095	9	10150	8	10205	9	10260	9	10315	9	10370	1	10425	9	10480	9	10535	6
9930	9	9985	9	10040	9	10095	9	10150	8	10205	9	10260	9	10315	9	10370	1	10425	9	10480	9	10535	6
9931	9	9985.5	9	10041	9	10096	9	10151	8	10206	9	10261	9	10316	9	10371	1	10426	9	10481	9	10536	6
9931	9	9986	9	10041	9	10096	9	10151	8	10206	9	10261	9	10316	9	10371	1	10426	9	10481	9	10536	6
9932	9	9986.5	9	10042	9	10097	9	10152	8	10207	9	10262	9	10317	9	10372	8	10427	9	10482	9	10537	6
9932	9	9987	9	10042	9	10097	9	10152	8	10207	9	10262	9	10317	9	10372	8	10427	9	10482	8	10537	6
9933	9	9987.5	9	10043	9	10098	9	10153	8	10208	9	10263	9	10318	9	10373	8	10428	9	10483	8	10538	6
9933	9	9988	9	10043	9	10098	9	10153	8	10208	9	10263	9	10318	9	10373	8	10428	9	10483	8	10538	6
9934	9	9988.5	9	10044	9	10099	9	10154	8	10209	9	10264	9	10319	9	10374	8	10429	9	10484	8	10539	6
9934	9	9989	9	10044	9	10099	9	10154	8	10209	9	10264	9	10319	9	10374	8	10429	9	10484	8	10539	6
9935	9	9989.5	9	10045	9	10100	9	10155	8	10210	9	10265	9	10320	9	10375	8	10430	9	10485	8	10540	9
9935	9	9990	9	10045	9	10100	9	10155	7	10210	9	10265	9	10320	9	10375	8	10430	9	10485	7	10540	6
9936	9	9990.5	9	10046	9	10101	9	10156	7	10211	9	10266	9	10321	9	10376	8	10431	9	10486	7	10541	9
9936	9	9991	9	10046	9	10101	9	10156	9	10211	9	10266	9	10321	9	10376	8	10431	9	10486	7	10541	9
9937	9	9991.5	9	10047	9	10102	9	10157	9	10212	9	10267	9	10322	9	10377	8	10432	9	10487	7	10542	9
9937	9	9992	9	10047	9	10102	9	10157	9	10212	9	10267	7	10322	9	10377	8	10432	9	10487	7	10542	9
9938	9	9992.5	9	10048	9	10103	9	10158	9	10213	9	10268	7	10323	9	10378	8	10433	9	10488	7	10543	9
9938	9	9993	9	10048	9	10103	9	10158	9	10213	9	10268	7	10323	9	10378	8	10433	9	10488	7	10543	9
9939	9	9993.5	9	10049	9	10104	9	10159	9	10214	9	10269	9	10324	9	10379	8	10434	9	10489	7	10544	9
9939	9	9994	9	10049	9	10104	9	10159	9	10214	9	10269	7	10324	9	10379	8	10434	8	10489	8	10544	9
9940	9	9994.5	9	10050	9	10105	9	10160	9	10215	9	10270	9	10325	9	10380	1	10435	8	10490	8	10545	9
9940	9	9995	9	10050	9	10105	9	10160	9	10215	9	10270	9	10325	9	10380	1	10435	8	10490	8	10545	9
9941	9	9995.5	9	10051	9	10106	9	10161	9	10216	9	10271	9	10326	9	10381	1	10436	8	10491	7	10546	9
9941	9	9996	9	10051	9	10106	9	10161	9	10216	9	10271	9	10326	9	10381	1	10436	8	10491	7	10546	9
9942	9	9996.5	9	10052	9	10107	9	10162	9	10217	9	10272	9	10327	9	10382	1	10437	9	10492	7	10547	9
9942	9	9997	9	10052	9	10107	9	10162	9	10217	9	10272	9	10327	9	10382	8	10437	9	10492	7	10547	9
9943	9	9997.5	9	10053	9	10108	9	10163	9	10218	9	10273	9	10328	9	10383	8	10438	9	10493	7	10548	6
9943	9	9998	9	10053	9	10108	9	10163	9	10218	9	10273	9	10328	9	10383	8	10438	9	10493	7	10548	9
9944	9	9998.5	9	10054	9	10109	9	10164	9	10219	9	10274	9	10329	9	10384	8	10439	9	10494	7	10549	9
9944	9	9999	9	10054	9	10109	9	10164	9	10219	9	10274	9	10329	9	10384	8	10439	9	10494	7	10549	9
9945	9	9999.5	9	10055	9	10110	9	10165	9	10220	9	10275	9	10330	9	10385	8	10440	9	10495	7	10550	9
9945	9	10000	9	10055	9	10110	9	10165	9	10220	9	10275	9	10330	9	10385	8	10440	9	10495	7	10550	9
9946	9	10001	9	10056	9	10111	9	10166	9	10221	9	10276	9	10331	9	10386	8	10441	9	10496	8	10551	9
9946	9	10001	9	10056	9	10111	9	10166	9	10221	9	10276	9	10331	9	10386	8	10441	9	10496	8	10551	9
9947	9	10002	9	10057	9	10112	9	10167	9	10222	9	10277	9	10332	9	10387	8	10442	9	10497	8	10552	9
9947	9	10002	9	10057	9	10112	9	10167	9	10222	9	10277	9	10332	9	10387	8	10442	9	10497	8	10552	9
9948	9	10003	9	10058	9	10113	9	10168	9	10223	9	10278	9	10333	9	10388	8	10443	9	10498	7	10553	9
9948	9	10003	9	10058	9	10113	9	10168	9	10223	9	10278	9	10333	9	10388	9	10443	9	10498	7	10553	9
9949	9	10004	9	10059	9	10114	9	10169	9	10224	9	10279	9	10334	9	10389	9	10444	9	10499	7	10554	9
9949	9	10004	9	10059	9	10114	9	10169	9	10224	9	10279	9	10334	9	10389	9	10444	1.2	10499	7	10554	9
9950	9	10005	9	10060	9	10115	9	10170	9	10225	9	10280	9	10335	9	10390	9	10445	9	10500	7	10555	9
9950	9	10005	9	10060	9	10115	9	10170	9	10225	9	10280	9	10335	9	10390	9	10445	9	10500	7	10555	9
9951	9	10006	9	10061	9	10116	9	10171	9	10226	9	10281	9	10336	9	10391	9	10446	9	10501	6	10556	9
9951	9	10006	9	10061	9	10116	9	10171	9	10226	9	10281	9	10336	9	10391	9	10446	9	10501	6	10556	9
9952	9	10007	9	10062	9	10117	9	10172	9	10227	9	10282	9	10337	9	10392	9	10447	9	10502	6	10557	9
9952	9	10007	9	10062	9	10117	9	10172	9	10227	9	10282	9	10337	9	10392	9	10447	9	10502	6	10557	9
9953	9	10008	9	10063	9	10118	9	10173	9	10228	9	10283	9	10338	9	10393	9	10448	9	10503	6	10558	9
9953	9	10008	9	10063	9	10118	9	10173	9	10228	9	10283	9	10338	9	10393	9	10448	9	10503	6	10558	9
9954	9	10009	9	10064	9	10119	9	10174	9	10229	9	10284	9	10339	9	10394	9	10449	9	10504	6	10559	9
9954	9	10009	9	10064	9	10119	9	10174	9	10229	9	10284	9	10339	9	10394	9	10449	9	10504	6	10559	9
9955	9	10010	9	10065	9	10120	9	10175	9	10230	9	10285	9	10340	9	10395	9	10450	9	10505	6	10560	9

DEP		DEP		DEP						DEP		DEP		DEP		DEP		DEP		DEP		DEP	
10560	9	10616	6	10670	9	DEP		DEP		10835	12	10890	9	10945	12	11000	4	11055	12	11110	4	11165	4
10561	9	10616	6	10671	9	10725	9	10780	9	10836	12	10891	9	10946	12	11001	10	11056	12	11111	12	11166	4
10561	9	10616	6	10671	9	10726	9	10781	9	10836	12	10891	9	10946	12	11001	4	11056	12	11111	12	11166	4
10562	9	10617	6	10672	9	10726	9	10781	9	10837	9	10892	9	10947	12	11002	4	11057	12	11112	12	11167	4
10562	9	10617	9	10672	9	10727	9	10782	9	10837	12	10892	12	10947	12	11002	4	11057	12	11112	12	11167	4
10563	9	10618	9	10673	9	10727	9	10782	9	10838	12	10893	12	10948	12	11003	12	11058	4	11113	12	11168	12
10563	9	10618	9	10673	9	10728	9	10783	9	10838	12	10893	12	10948	12	11003	4	11058	4	11113	12	11168	12
10564	9	10619	9	10674	9	10728	9	10783	9	10839	12	10894	12	10949	12	11004	4	11059	4	11114	12	11169	12
10564	9	10619	9	10674	9	10729	9	10784	9	10839	12	10894	12	10949	12	11004	4	11059	12	11114	12	11169	12
10565	9	10620	9	10675	12	10729	9	10784	9	10840	12	10895	12	10950	12	11005	4	11060	12	11115	12	11170	12
10565	9	10620	9	10675	12	10730	9	10785	9	10840	12	10895	12	10950	12	11005	4	11060	12	11115	12	11170	12
10566	9	10621	9	10676	12	10730	9	10785	9	10841	12	10896	12	10951	12	11006	4	11061	12	11116	12	11171	12
10566	9	10621	6	10676	12	10731	9	10786	12	10841	12	10896	12	10951	12	11006	10	11061	12	11116	12	11171	12
10567	9	10622	6	10677	12	10731	9	10786	9	10842	9	10897	12	10952	12	11007	10	11062	12	11117	12	11172	12
10567	9	10622	6	10677	12	10732	9	10787	9	10842	9	10897	9	10952	12	11007	4	11062	12	11117	4	11172	12
10568	9	10623	9	10678	12	10732	9	10787	9	10843	9	10898	12	10953	12	11008	4	11063	12	11118	4	11173	12
10568	9	10623	9	10678	12	10733	9	10788	9	10843	9	10898	12	10953	12	11008	10	11063	12	11118	4	11173	12
10569	9	10624	9	10679	12	10733	9	10788	12	10844	9	10899	12	10954	12	11009	10	11064	12	11119	4	11174	12
10569	9	10624	6	10679	12	10734	9	10789	9	10844	9	10899	12	10954	12	11009	10	11064	12	11119	4	11174	12
10570	9	10625	6	10680	12	10734	9	10789	9	10845	9	10900	12	10955	12	11010	4	11065	12	11120	12	11175	4
10570	9	10625	9	10680	12	10735	9	10790	9	10845	9	10900	12	10955	12	11010	4	11065	12	11120	12	11175	4
10571	9	10626	9	10681	12	10735	9	10790	9	10846	9	10901	12	10956	12	11011	4	11066	12	11121	4	11176	4
10571	9	10626	9	10681	12	10736	9	10791	9	10846	9	10901	12	10956	12	11011	12	11066	12	11121	4	11176	4
10572	9	10627	9	10682	12	10736	9	10791	9	10847	12	10902	12	10957	12	11012	12	11067	12	11122	12	11177	4
10572	9	10627	9	10682	9	10737	9	10792	9	10847	12	10902	12	10957	12	11012	12	11067	12	11122	12	11177	12
10573	9	10628	9	10683	9	10737	9	10792	9	10848	9	10903	4	10958	12	11013	12	11068	4	11123	12	11178	12
10573	9	10628	9	10683	9	10738	9	10793	9	10848	9	10903	12	10958	12	11013	12	11068	12	11123	12	11178	12
10574	9	10629	9	10684	9	10738	9	10793	9	10849	9	10904	12	10959	12	11014	12	11069	4	11124	12	11179	12
10574	9	10629	9	10684	9	10739	9	10794	9	10849	9	10904	12	10959	12	11014	12	11069	4	11124	12	11179	12
10575	9	10630	9	10685	9	10739	9	10794	9	10850	12	10905	12	10960	12	11015	12	11070	12	11125	12	11180	12
10575	9	10630	9	10685	9	10740	9	10795	9	10850	12	10906	12	10960	12	11015	12	11070	12	11125	12	11180	12
10576	9	10631	9	10686	9	10740	9	10795	9	10851	9	10906	12	10961	12	11016	12	11071	12	11126	12	11181	12
10576	9	10631	6	10686	9	10741	9	10796	9	10851	9	10906	12	10961	12	11016	12	11071	4	11126	12	11181	12
10577	9	10632	9	10687	9	10741	9	10796	9	10852	9	10907	12	10962	12	11017	12	11072	12	11127	12	11182	12
10577	9	10632	9	10687	9	10742	9	10797	9	10852	9	10907	12	10962	12	11017	12	11072	12	11127	12	11182	12
10578	9	10633	9	10688	9	10742	9	10797	9	10853	9	10908	12	10963	12	11018	12	11073	12	11128	12	11183	12
10578	9	10633	9	10688	9	10743	9	10798	9	10853	9	10908	12	10963	12	11018	12	11073	12	11128	12	11183	12
10579	9	10634	9	10689	9	10743	9	10798	9	10854	9	10909	12	10964	12	11019	12	11074	4	11129	12	11184	12
10579	9	10634	9	10689	9	10744	9	10799	9	10854	9	10909	12	10964	12	11019	12	11074	12	11129	12	11184	12
10580	9	10635	9	10690	9	10744	9	10799	9	10855	9	10910	12	10965	12	11020	12	11075	12	11130	12	11185	12
10580	9	10635	9	10690	9	10745	9	10800	9	10855	9	10910	12	10965	12	11020	12	11075	4	11130	12	11185	12
10581	9	10636	9	10691	9	10745	9	10800	9	10856	9	10911	12	10966	12	11021	12	11076	10	11131	12	11186	12
10581	9	10636	9	10691	9	10746	9	10801	9	10856	9	10911	12	10966	12	11021	12	11076	10	11131	12	11186	12
10582	9	10637	9	10692	9	10746	9	10801	9	10857	9	10912	12	10967	12	11022	12	11077	4	11132	12	11187	12
10582	9	10637	9	10692	9	10747	9	10802	9	10857	12	10912	12	10967	12	11022	12	11077	4	11132	12	11187	12
10583	9	10638	9	10693	9	10747	9	10802	9	10858	12	10913	12	10968	12	11023	12	11078	4	11133	4	11188	12
10583	9	10638	9	10693	9	10748	12	10803	12	10858	12	10913	12	10968	9	11023	12	11078	4	11133	4	11188	12
10584	9	10639	9	10694	9	10748	9	10803	9	10859	12	10914	12	10969	9	11024	12	11079	4	11134	4	11189	12
10584	9	10639	9	10694	9	10749	9	10804	9	10859	9	10914	12	10969	9	11024	12	11079	4	11134	12	11189	12
10585	9	10640	9	10695	9	10749	9	10804	9	10860	12	10915	12	10970	12	11025	12	11080	12	11135	12	11190	12
10585	9	10640	9	10695	9	10750	12	10805	9	10860	12	10915	12	10970	12	11025	12	11080	12	11135	12	11190	4
10586	9	10641	9	10696	9	10750	12	10805	9	10861	12	10916	12	10971	12	11026	12	11081	12	11136	12	11191	4
10586	9	10641	9	10696	9	10751	9	10806	9	10861	12	10916	12	10971	9	11026	12	11081	12	11136	12	11191	4
10587	9	10642	12	10697	9	10751	9	10806	9	10862	12	10917	12	10972	9	11027	12	11082	12	11137	12	11192	10
10587	9	10642	12	10697	9	10752	9	10807	12	10862	12	10917	12	10972	9	11027	12	11082	12	11137	12	11192	10
10588	9	10643	9	10698	9	10752	9	10807	9	10863	12	10918	12	10973	9	11028	12	11083	12	11138	12	11193	4
10588	9	10643	9	10698	9	10753	9	10808	9	10863	12	10918	12	10973	9	11028	12	11083	12	11138	12	11193	4
10589	9	10644	9	10699	9	10753	9	10808	9	10864	12	10919	12	10974	9	11029	12	11084	12	11139	12	11194	10
10589	9	10644	9	10699	9	10754	9	10809	9	10864	12	10919	12	10974	9	11029	12	11084	12	11139	4	11194	10
10590	9	10645	9	10700	9	10754	9	10809	9	10865	12	10920	12	10975	9	11030	12	11085	12	11140	12	11195	12
10590	9	10645	9	10700	9	10755	9	10810	9	10865	12	10920	12	10975	9	11030	12	11085	12	11140	12	11195	12
10591	9	10646	9	10701	9	10755	9	10810	9	10866	12	10921	12	10976	9	11031	12	11086	12	11141	12	11196	12
10591	9	10646	9	10701	9	10756	9	10811	9	10866	12	10921	12	10976	9	11031	12	11086	4	11141	4	11196	12
10592	9	10647	9	10702	9	10756	9	10811	9	10867	12	10922	12	10977	9	11032	12	11087	12	11142	4	11197	12
10592	9	10647	9	10702	9	10757	9	10812	9	10867	12	10922	12	10977	9	11032	12	11087	12	11142	4	11197	12
10593	9	10648	9	10703	9	10757	9	10812	9	10868	9	10923	12	10978	9	11033	12	11088	12	11143	4	11198	12
10593	9	10648	9	10703	9	10758	12	10813	9	10868	9	10923	12	10978	9	11033	12	11088	12	11143	4	11198	12
10594	9	10649	9	10704	9	10758	12	10813	9	10869	9	10924	12	10979	9	11034	12	11089	12	11144	4	11199	12
10594	9	10649	9	10704	9	10759	12	10814	9	10869	9	10924	12	10979	9	11034	12	11089	12	11144	4	11199	12
10595	9	10650	9	10705	9	10759	12	10814	9	10870	9	10925	4	10980	9	11035	12	11090	12	11145	12	11200	4
10595	9	10650	9	10705	9	10760	12	10815	9	10870	12	10925	12	10980	9	11035	12	11090	12	11145	12	11200	4
10596	9	10651	9	10706	9	10760	12	10815	9	10871	12	10926	12	10981	12	11036	12	11091	4	11146	12	11201	4
10596	9	10651	9	10706	9	10761	12	10816	9	10871	12	10926	12	10981	12	11036	12	11091	4	11146	12	11201	4
10597	9	10652	9	10707	9	10761	12	10816	9	10872	12	10927	12	10982	12	11037	12	11092	12	11147	4	11202	4
10597	9	10652	9	10707	9	10762	12	10817	9	10872	12	10927	12	10982	12	11037	12	11092	4	11147	4	11202	4
10598	9	10653	9	10708	9	10762	12	10817	9	10873	12	10928	12	10983	12	11038	12	11093	4	11148	4	11203	12
10598	9	10653	9	10708	9	10763	12	10818	9	10873	12	10928	12	10983	12	11038	12	11093	4	11148	4	11203	12
10599	9	10654	9	10709	9	10763	12	10818	9	10874	9	10929	12	10984	12	11039	12	11094	4	11149	4	11204	12
10599	9	10654	9	10709	9	10764	12	10819	9	10874	9	10929	12	10984	12	11039	12	11094	4	11149	4	11204	12
10600	9	10655	9	10710	9	10764	12	10819	9	10875	9	10930	12	10985	12	11040	12	11095	4	11150	4	11205	4
10600	9	10655	9	10710	9	10765	12	10820	9	10875	9	10930	12	10985	12	11040	12	11095	12	11150	4	11205	12
10601	9	10656	9	10711	9	10765	12	10820	9	10876	9	10931	12	10986	12	11041	12	11096	12	11151	4	11206	12
10601	9	10656	9	10711	9	10766	9	10821	9	10876	9	10931	12	10986	12	11041	12	11096	12	11151	4	11206	12
10602	9	10657	9	10712	9	10766	9	10821	9	10877	9	10932	12	10987	12	11042	12	11097	12	11152	12	11207	4
10602	7	10657	9	10712	9	10767	12	10822	9	10877	9	10932	12	10987	12	11042	12	11097	12	11152	12	11207	10
10603	9	10658	9	10713	9	10767	12	10822	9	10878	9	10933	12	10988	12	11043	12	11098	12	11153	12	11208	10
10603	9	10658	9	10713	9	10768	12	10823	9	10878	9	10933	12	10988	12	11043	12	11098	12	11153	12	11208	4
10604	7	10659	9	10714	9	10768	12	10823	9	10879	9	10934	12	10989	12	11044	12	11099	12	11154	12	11209	4
10604	9	10659	9	10714	9	10769	12	10824	9	10879	9	10934	12	10989	12	11044	12	11099	12	11154	12	11209	10
10605	9	10660	9	10715	9	10769	9	10824	9	10880	9	10935	12	10990	12	11045	12	11100	12	11155	4	11210	10
10605	9	10660	9	10715	12	10770	12	10825	9	10880	9	10935	12	10990	12	11045	12	11100	12	11155	4	11210	10
10606	9	10661	9	10716	12	10770	9	10825	12	10881	9	10936	12	10991	12	11046	12	11101	12	11156	4	11211	4
10606	9	10661	9	10716	12	10771	9	10826	12	10881	9	10936	12	10991	12	11046	4	11101	12	11156	12	11211	4
10607	9	10662	9	10717	12	10771	12	10826	12	10882	9	10937	12	10992	12	11047	10	11102	4	11157	12	11212	4
10607	9	10662	9	10717	12	10772	12	10827	9	10882	9	10937	12	10992	12	11047	12	11102	4	11157	12	11212	10
10608	9	10663	9	10718	12	10772	9	10827	9	10883	9	10938	12	10993	12	11048	12	11103	4	11158	12	11213	10
10608	9	10663	9	10718	9	10773	9	10828	9	10883	12	10938	12	10993	12	11048	10	11103	4	11158	12	11213	4
10609	9	10664	9	10719	9	10773	9	10828	9	10884	12	10939	12	10994	12	11049	10	11104	12	11159	12	11214	4
10609	9	10664	9	10719	9	10774	9	10829	9	10884	12	10939	12	10994	12	11049	10	11104	12	11159	12	11214	4
10610	9	10665	9	10720	9	10774	9	10829	9	10885	12	10940	12	10995	12	11050	12	11105	12	11160	12	11215	4
10610	9	10665	9	10720	9	10775	9	10830	9	10885	12	10940	12	10995	12	11050	12	11105	4	11160	12	11215	4
10611	9	10666	9	10721	9	10775	9	10830	9	10886	12	10941	12	10996	12	11051	12	11106	4	11161	12	11216	10
10611	6	10666	9	10721	12	10776	9	10831	9	10886	12	10941	10	10996	12	11051	12	11106	4	11161	4	11216	10
10612	9	10667	9	10722	12	10776	9	10831	9	10887	12	10942	10	10997	12	11052	12	11107	4	11162	4	11217	10
10612	9	10667	9	10722	9	10777	9	10832	9	10887	12	10942	10	10997	12	11052	12	11107	4	11162	4	11217	10
10613	9	10668	9	10723	9	10777	9	10832	9	10888	12	10943	12	10998	12	11053	12	11108	4	11163	12	11218	4
10613	9	10668	9	10723	9	10778	9	10833	9	10888	12	10943	12	10998	4	11053	12	11108	4	11163	12	11218	4
10614	6	10669	9	10724	9	10778	9	10833	9	10889	12	10944	12	10999	12	11054	12	11109	4	11164	12	11219	4
10614	6	10669	9	10724	9	10779	9	10834	9	10889	12	10944	12	10999	12	11054	12	11109	4	11164	12	11219	4
10615	6	10670	9	10725	9	10779	9	10834	12	10890	9	10945	12	11000	12	11055	12	11110	4	11165	4	11220	10

DEP		DEP		DEP		DEP		DEP		DEP		DEP		DEP		DEP		DEP		DEP		DEP	
11220	10	11276	4	11330	4	11385	3	11440	4	11495	4	11550	10	11605	4	11660	12	11715	4	11770	4	11825	10
11221	4	11276	4	11331	4	11386	3	11441	12	11496	4	11551	10	11606	4	11661	12	11716	4	11771	4	11826	10
11221	10	11276	4	11331	12	11386	3	11441	12	11496	4	11551	10	11606	10	11661	4	11716	10	11771	12	11826	10
11222	4	11277	4	11332	12	11387	3	11442	12	11497	12	11552	10	11607	10	11662	4	11717	10	11772	12	11827	10
11222	4	11277	4	11332	12	11387	3	11442	4	11497	12	11552	10	11607	10	11662	4	11717	4	11772	10	11827	10
11223	4	11278	4	11333	12	11388	3	11443	4	11498	12	11553	10	11608	10	11663	4	11718	12	11773	10	11828	10
11223	4	11278	4	11333	12	11388	3	11443	4	11498	12	11553	10	11608	10	11663	4	11718	12	11773	10	11828	10
11224	10	11279	4	11334	12	11389	3	11444	4	11499	12	11554	10	11609	10	11664	4	11719	12	11774	10	11829	10
11224	4	11279	4	11334	12	11389	4	11444	4	11499	4	11554	10	11609	10	11664	4	11719	10	11774	10	11829	10
11225	4	11280	4	11335	12	11390	4	11445	4	11500	4	11555	4	11610	10	11665	4	11720	10	11775	10	11830	10
11225	4	11280	4	11335	12	11390	4	11445	4	11500	12	11555	4	11610	10	11665	12	11720	10	11775	10	11830	10
11226	4	11281	4	11336	12	11391	4	11446	10	11501	12	11556	4	11611	10	11666	12	11721	10	11776	10	11831	10
11226	4	11281	4	11336	4	11391	4	11446	4	11501	12	11556	4	11611	10	11666	12	11721	4	11776	10	11831	10
11227	4	11282	4	11337	4	11392	4	11447	4	11502	12	11557	10	11612	10	11667	12	11722	10	11777	10	11832	10
11227	4	11282	4	11337	4	11392	4	11447	4	11502	12	11557	10	11612	10	11667	12	11722	10	11777	10	11832	10
11228	4	11283	4	11338	12	11393	4	11448	10	11503	12	11558	10	11613	10	11668	4	11723	4	11778	10	11833	10
11228	4	11283	4	11338	12	11393	4	11448	4	11503	12	11558	10	11613	10	11668	10	11723	12	11778	10	11833	10
11229	4	11284	4	11339	12	11394	4	11449	4	11504	12	11559	10	11614	10	11669	10	11724	12	11779	10	11834	10
11229	4	11284	4	11339	12	11394	4	11449	4	11504	12	11559	10	11614	10	11669	10	11724	4	11779	10	11834	10
11230	4	11285	4	11340	4	11395	4	11450	4	11505	12	11560	10	11615	10	11670	10	11725	10	11780	10	11835	10
11230	4	11285	4	11340	4	11395	4	11450	4	11505	12	11560	10	11615	10	11670	10	11725	4	11780	10	11835	10
11231	4	11286	4	11341	4	11396	4	11451	4	11506	12	11561	10	11616	10	11671	10	11726	12	11781	10	11836	10
11231	4	11286	4	11341	12	11396	4	11451	4	11506	12	11561	10	11616	10	11671	10	11726	12	11781	10	11836	10
11232	12	11287	4	11342	12	11397	4	11452	4	11507	12	11562	10	11617	12	11672	10	11727	4	11782	10	11837	10
11232	12	11287	4	11342	12	11397	4	11452	10	11507	12	11562	10	11617	12	11672	10	11727	4	11782	10	11837	10
11233	12	11288	3	11343	12	11398	4	11453	10	11508	12	11563	10	11618	12	11673	10	11728	4	11783	10	11838	10
11233	12	11288	3	11343	12	11398	4	11453	10	11508	10	11563	10	11618	12	11673	10	11728	10	11783	10	11838	10
11234	12	11289	3	11344	12	11399	4	11454	10	11509	10	11564	10	11619	4	11674	10	11729	10	11784	10	11839	10
11234	12	11289	3	11344	12	11399	4	11454	10	11509	10	11564	10	11619	4	11674	10	11729	10	11784	10	11839	10
11235	12	11290	3	11345	4	11400	4	11455	10	11510	10	11565	10	11620	4	11675	10	11730	10	11785	10	11840	10
11235	12	11290	3	11345	4	11400	4	11455	10	11510	10	11565	10	11620	4	11675	10	11730	10	11785	10	11840	10
11236	12	11291	3	11346	12	11401	10	11456	4	11511	10	11566	10	11621	12	11676	10	11731	10	11786	10	11841	10
11236	12	11291	3	11346	12	11401	4	11456	4	11511	10	11566	10	11621	12	11676	10	11731	4	11786	10	11841	10
11237	12	11292	4	11347	12	11402	4	11457	12	11512	10	11567	10	11622	4	11677	10	11732	4	11787	10	11842	10
11237	4	11292	4	11347	12	11402	4	11457	12	11512	10	11567	10	11622	4	11677	4	11732	4	11787	10	11842	10
11238	4	11293	4	11348	12	11403	4	11458	12	11513	10	11568	10	11623	10	11678	12	11733	4	11788	10	11843	4
11238	4	11293	4	11348	12	11403	12	11458	12	11513	10	11568	10	11623	4	11678	4	11733	4	11788	10	11843	4
11239	10	11294	4	11349	12	11404	4	11459	12	11514	4	11569	4	11624	12	11679	4	11734	10	11789	10	11844	4
11239	10	11294	4	11349	12	11404	4	11459	12	11514	4	11569	4	11624	12	11679	4	11734	10	11789	10	11844	4
11240	10	11295	4	11350	4	11405	4	11460	4	11515	4	11570	4	11625	12	11680	10	11735	10	11790	10	11845	4
11240	10	11295	12	11350	4	11405	4	11460	4	11515	10	11570	10	11625	4	11680	4	11735	10	11790	10	11845	4
11241	4	11296	4	11351	4	11406	4	11461	4	11516	10	11571	10	11626	4	11681	10	11736	10	11791	10	11846	4
11241	4	11296	4	11351	12	11406	4	11461	4	11516	10	11571	10	11626	4	11681	10	11736	10	11791	10	11846	4
11242	4	11297	4	11352	12	11407	12	11462	10	11517	10	11572	10	11627	10	11682	10	11737	10	11792	10	11847	4
11242	4	11297	4	11352	4	11407	12	11462	10	11517	10	11572	10	11627	4	11682	10	11737	10	11792	10	11847	4
11243	4	11298	4	11353	12	11408	12	11463	4	11518	10	11573	10	11628	4	11683	10	11738	10	11793	10	11848	4
11243	4	11298	4	11353	12	11408	12	11463	4	11518	10	11573	10	11628	4	11683	12	11738	10	11793	10	11848	4
11244	4	11299	4	11354	4	11409	12	11464	4	11519	4	11574	4	11629	4	11684	12	11739	10	11794	10	11849	10
11244	10	11299	4	11354	4	11409	12	11464	4	11519	10	11574	10	11629	4	11684	12	11739	10	11794	10	11849	10
11245	4	11300	4	11355	4	11410	12	11465	4	11520	10	11575	10	11630	4	11685	12	11740	10	11795	10	11850	10
11245	4	11300	4	11355	4	11410	4	11465	4	11520	10	11575	4	11630	4	11685	12	11740	10	11795	10	11850	10
11246	4	11301	4	11356	4	11411	12	11466	4	11521	10	11576	10	11631	4	11686	12	11741	10	11796	10	11851	10
11246	4	11301	10	11356	4	11411	12	11466	4	11521	10	11576	10	11631	3	11686	12	11741	10	11796	12	11851	10
11247	4	11302	4	11357	4	11412	4	11467	12	11522	10	11577	10	11632	3	11687	12	11742	10	11797	10	11852	4
11247	4	11302	4	11357	12	11412	4	11467	4	11522	10	11577	10	11632	2	11687	4	11742	10	11797	10	11852	10
11248	12	11303	4	11358	12	11413	4	11468	4	11523	10	11578	10	11633	3	11688	10	11743	10	11798	10	11853	10
11248	4	11303	12	11358	12	11413	4	11468	4	11523	10	11578	10	11633	3	11688	10	11743	10	11798	10	11853	10
11249	12	11304	12	11359	12	11414	12	11469	4	11524	10	11579	10	11634	2	11689	10	11744	10	11799	10	11854	10
11249	12	11304	4	11359	12	11414	4	11469	4	11524	10	11579	10	11634	4	11689	10	11744	10	11799	10	11854	10
11250	12	11305	4	11360	4	11415	12	11470	4	11525	10	11580	10	11635	4	11690	10	11745	10	11800	10	11855	10
11250	12	11305	4	11360	4	11415	4	11470	4	11525	10	11580	10	11635	4	11690	10	11745	10	11800	10	11855	10
11251	12	11306	4	11361	12	11416	4	11471	4	11526	10	11581	10	11636	4	11691	10	11746	10	11801	10	11856	10
11251	12	11306	4	11361	12	11416	10	11471	4	11526	10	11581	10	11636	4	11691	10	11746	10	11801	10	11856	10
11252	12	11307	4	11362	12	11417	10	11472	4	11527	10	11582	10	11637	12	11692	10	11747	10	11802	10	11857	10
11252	12	11307	10	11362	12	11417	10	11472	4	11527	10	11582	4	11637	12	11692	10	11747	10	11802	10	11857	10
11253	12	11308	10	11363	12	11418	10	11473	4	11528	10	11583	4	11638	12	11693	10	11748	10	11803	10	11858	10
11253	12	11308	4	11363	12	11418	10	11473	4	11528	10	11583	12	11638	4	11693	10	11748	10	11803	10	11858	10
11254	12	11309	12	11364	12	11419	10	11474	4	11529	10	11584	4	11639	4	11694	4	11749	10	11804	10	11859	10
11254	4	11309	12	11364	12	11419	10	11474	4	11529	10	11584	12	11639	12	11694	4	11749	10	11804	10	11859	10
11255	4	11310	12	11365	12	11420	4	11475	4	11530	10	11585	4	11640	12	11695	4	11750	10	11805	10	11860	10
11255	4	11310	12	11365	12	11420	4	11475	4	11530	10	11585	4	11640	12	11695	4	11750	10	11805	10	11860	10
11256	4	11311	12	11366	12	11421	4	11476	4	11531	10	11586	10	11641	12	11696	4	11751	10	11806	10	11861	10
11256	4	11311	12	11366	12	11421	10	11476	4	11531	10	11586	10	11641	4	11696	4	11751	10	11806	10	11861	10
11257	4	11312	12	11367	11	11422	10	11477	4	11532	10	11587	10	11642	4	11697	4	11752	10	11807	10	11862	10
11257	4	11312	12	11367	3	11422	10	11477	4	11532	10	11587	10	11642	4	11697	4	11752	10	11807	10	11862	10
11258	4	11313	4	11368	3	11423	10	11478	4	11533	10	11588	10	11643	4	11698	4	11753	10	11808	10	11863	10
11258	4	11313	4	11368	3	11423	10	11478	12	11533	10	11588	10	11643	12	11698	4	11753	10	11808	10	11863	10
11259	4	11314	4	11369	4	11424	10	11479	12	11534	10	11589	10	11644	12	11699	4	11754	10	11809	10	11864	10
11259	4	11314	4	11369	4	11424	10	11479	12	11534	10	11589	10	11644	12	11699	3	11754	10	11809	10	11864	10
11260	4	11315	12	11370	4	11425	10	11480	12	11535	10	11590	10	11645	12	11700	4	11755	10	11810	10	11865	10
11260	12	11315	12	11370	12	11425	10	11480	12	11535	10	11590	10	11645	12	11700	4	11755	10	11810	10	11865	10
11261	12	11316	12	11371	12	11426	10	11481	12	11536	10	11591	10	11646	12	11701	4	11756	10	11811	10	11866	12
11261	4	11316	4	11371	4	11426	10	11481	12	11536	10	11591	10	11646	4	11701	4	11756	10	11811	10	11866	12
11262	12	11317	12	11372	4	11427	10	11482	12	11537	10	11592	10	11647	4	11702	4	11757	10	11812	10	11867	12
11262	4	11317	12	11372	4	11427	10	11482	12	11537	10	11592	10	11647	4	11702	4	11757	10	11812	10	11867	10
11263	3	11318	4	11373	4	11428	10	11483	4	11538	10	11593	10	11648	4	11703	4	11758	10	11813	10	11868	10
11263	3	11318	4	11373	3	11428	10	11483	4	11538	10	11593	10	11648	4	11703	4	11758	10	11813	10	11868	10
11264	3	11319	10	11374	3	11429	10	11484	4	11539	10	11594	10	11649	12	11704	4	11759	10	11814	10	11869	10
11264	4	11319	4	11374	3	11429	10	11484	4	11539	10	11594	10	11649	12	11704	4	11759	10	11814	10	11869	10
11265	4	11320	4	11375	3	11430	10	11485	4	11540	10	11595	10	11650	12	11705	4	11760	10	11815	10	11870	10
11265	4	11320	4	11375	3	11430	10	11485	3	11540	10	11595	10	11650	12	11705	4	11760	4	11815	10	11870	10
11266	4	11321	4	11376	3	11431	10	11486	3	11541	10	11596	10	11651	12	11706	4	11761	4	11816	10		
11266	4	11321	4	11376	4	11431	10	11486	3	11541	10	11596	10	11651	4	11706	12	11761	4	11816	10		
11267	4	11322	4	11377	12	11432	10	11487	3	11542	10	11597	10	11652	4	11707	12	11762	4	11817	10		
11267	4	11322	4	11377	12	11432	10	11487	4	11542	10	11597	10	11652	4	11707	12	11762	12	11817	10		
11268	4	11323	4	11378	12	11433	10	11488	4	11543	10	11598	10	11653	4	11708	4	11763	4	11818	10		
11268	4	11323	4	11378	12	11433	10	11488	4	11543	10	11598	10	11653	4	11708	4	11763	4	11818	10		
11269	4	11324	4	11379	12	11434	10	11489	4	11544	10	11599	4	11654	4	11709	4	11764	4	11819	10		
11269	4	11324	4	11379	3	11434	10	11489	12	11544	10	11599	4	11654	4	11709	4	11764	4	11819	10		
11270	4	11325	4	11380	3	11435	10	11490	3	11545	10	11600	10	11655	12	11710	4	11765	4	11820	10		
11270	4	11325	4	11380	3	11435	10	11490	11	11545	10	11600	10	11655	12	11710	4	11765	4	11820	10		
11271	4	11326	4	11381	3	11436	10	11491	3	11546	10	11601	10	11656	4	11711	12	11766	4	11821	10		
11271	4	11326	4	11381	3	11436	10	11491	3	11546	10	11601	4	11656	4	11711	4	11766	4	11821	10		
11272	4	11327	4	11382	3	11437	10	11492	1	11547	10	11602	4	11657	4	11712	12	11767	4	11822	10		
11272	4	11327	12	11382	3	11437	10	11492	1	11547	10	11602	4	11657	4	11712	4	11767	4	11822	10		
11273	4	11328	12	11383	3	11438	4	11493	1	11548	10	11603	4	11658	12	11713	10	11768	4	11823	10		
11273	4	11328	4	11383	3	11438	10	11493	1	11548	10	11603	4	11658	4	11713	10	11768	4	11823	10		
11274	4	11329	10	11384	3	11439	10	11494	3	11549	10	11604	4	11659	4	11714	10	11769	4	11824	10		
11274	4	11329	10	11384	3	11439	10	11494	2	11549	10	11604	10	11659	4	11714	10	11769	4	11824	10		
11275	4	11330	4	11385	11	11440	10	11495	3	11550	10	11605	4	11660	12	11715	10	11770	4	11825	10		

Cluster No	Lithology	Legend
1	Pay sand	1
2	Pay sand	2
3	Pay sand	3
4	Shale	4
5	Pay sand	5
6	Wet sand	6
7	Pay sand	7
8	Pay sand	8
9	Shale	9
10	Shale	10
11	Pay sand	11
12	Shale	12

Fig. 2: Well stratigraphy chart

Table 3: Interpretation of SOM software clusters

Cluster No	Lithology
1	Pay sand
2	Pay sand
3	Pay sand
4	Shale
5	Pay sand
6	Wet sand
7	Pay sand
8	Pay sand
9	Shale
10	Shale
11	Pay sand
12	Shale

and standard deviation of the cluster groups were computed. The standard deviation measures the spread of the data about the mean value gives an indication of the effectiveness of the clusters generated. Table 2 presents the clusters (represented by a number label) identified in the log data, their mean values and their standard deviation.

The fuzzy inference process started with the fuzzification subprocess where the membership functions defined on the input variables were applied to their actual values to determine the degree of truth for each rule premise. If a rules premise has a non-zero degree of truth, then the rule fires. In the inference subprocess, the truth-value of each rule was computed and applied to its conclusion part. The fuzzy 'max' rule of composition of inferences was then applied. The results showing the lithology of the well inferred from the cluster groups is presented in Table 3.

Figure 2 presents a chart of the oil well showing the location of the different types of rock materials in the well. On the chart, the depth intervals containing pay sand is represented by the yellow colored regions, depth intervals containing wet sand with water content is represented by the blue colored regions. Regions where shales (or shaly rock materials) can be found are shown in ochre. Clusters 4, 9, 10 and 12 represent shales. It can be observed that the difference between these shale clusters is a progressive increase in the shale density. Clusters 1, 2, 3, 5, 7, 8 and 11 represents pay sand clusters. It can also be observed that there is a reduction in pay sand density with increase in pay sand resistivity values. Cluster 6 represents a wet sand cluster. A log analyst that was familiar with the data set used verified the result of the case study program. The chart shows relatively thin layers of sand interbedded within thick and expansive shale units (Adesida *et al*., 2006).

CONCLUSION

In this study, the SOM neural network has been used to analyze well log data obtained from the Niger-Delta region of Nigeria in order to extract knowledge from the well log data. The fuzzy inference methodology adopted in the interpretation of the clusters were derived from the methods used in the interpretation of traditional graphical cross-plots by log analysts. Well logs characteristic response in different rock materials were used to formulate fuzzy rules, which were used to identify the lithology represented by the clusters generated by the SOM from well log data.

While it is only the fuzzy rules relevant to the lithology determination program that have been extracted in this research, it is noted that the rule base actually accommodates all possible rock materials that may be of further interest in future research work. With the three logs used that is gamma ray log, resistivity log and density log, lithology discrimination has been achieved. However, better resolution could still be obtained with associated fluid content determination carried out by using logs that can be used to discriminate between fluids like the neutron log, although this tends to increase the number of fuzzy rule that can be derived from the logs.

The fuzzy rules can form the basis for the development of a software tool. A neuro-fuzzy expert system which can use the SOM neural networks clustering algorithm as a pre-processor for a fuzzy classification module. Or a fuzzy logic expert system since the fuzzy rule can also be incorporated into a software application that can directly classify the log values by fuzzify them, analyzing them and then classifying the individual log elements using the fuzzy rules. The software tool can be used by log analyst to determine the lithology and fluid content of an oil well prior to further processing of the log data in absence of core data.

REFERENCES

Adesida, A., J.S. Ojo and A. Fasakin, 2006. 3-D Geostatistical modeling of Shale content from the Champions Field, Niger Delta, NAPE Conference Proceedings, Akande *et al*. (Eds.)., pp: 51-54.

Barlai, Z., 2002. Principal Component Analysis and Applications, Crain's Petrophysical Handbook, c. 1978-2005 E.R. Crain.

Box 29 Site 3 RR 2, Rocky Mountain House, Alberta Canada T4T 2A2 403-845-2527, Updated 2004.

Chang, H., D. Kopaska-Merkel and Chen, 2002. Identification of lithofacies using Kohonen Self-Organizing Maps, Computers and Geosciences, 28: 223-229.

Chang, H., D. Kopaska-Merkel and Chen, 2000. Lithofacies identification using Multiple Adaptive Resonance Theory Neural Networks and Group Decision Expert System. Comput. Geosci., 26: 591-601.

Chikhi, S., M. Batouche and H. Shout, 2004. Hybrid Neural Network Methods for Lithology Identification in the Algerian Sahara. Int. J. Computational Intelligence, 1: 31-38.

Ford, D.A. and M.C. Kelly, 2001, Using Neural networks to Predict lithology from Well Logs, SEG Int'l Exposition and Annual meeting, San Antonio, Texas.

Kohonen, T., 1995. The Self-Organizing Map (SOM), Helsinki University of Technology, Laboratory of Computer and Information Science, Neura; Networks Research Centre, Quinquennial Report (1994-1998).

Mohaghegh, S., 2000. Virtual Intelligence Applications in Petroleum Engineering: Part 1-Artificial Neural Networks. J. Petroleum Tech., Distinguished Author Series, pp: 64-73.

Nikravesh, M. and F. Aminzadeh, 2002. Soft Computing for Reservoir Characterization, Berkeley Initiative in Soft Computing (BISC) Program, Computer Science Division-Department of EECS, University of California, Berkeley, CA 94720 and dGB-USA, Houston, TX.

Rider, M.H., 1996. The Geological Interpretation of Well Logs, Whittles Publishing. 2nd Edn. ISBN 1-870325-36-2.

Soto, B.R. and S.A. Holditch, 1999, Development of Reservoir Characterization Models using Core, Well log and 3D Seismic Data and Intelligent Software. The 1999 Society of Petroleum Engineers (SPE) Eastern Regional Conference and Exhibition, Charleston, WV.

Statsoft Electronic Statistics Textbook, 2002. Copyright, 1984-2003, (http://www.statsoftinc.com/txtbook/glosd.html#Data Mining).

Tuttle, M.L.W., R.R. Charpentier and M.E. Brownfield, 1999. The Niger Delta Petroleum System: Niger Delta Province, Nigeria, Cameroon and Equatorial Guinea, Africa, Central Region Energy Resources Team, U. S. Department of the Interior U.S. Geological Survey, Open-File Report 99-50-H.

Zadeh, L.A., 1965. Fuzzy Sets, Information and Control, 8: 333-353.