Deltaic Systems with Fluvial Dominion Interpretation using Artificial Neural Networks.

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Abstract: In this work, it will be presented an Artificial Neural Networks application for identifying the appropriate deltaic systems with fluvial dominion using Petrology characteristics, physical and paleontological sedimentologics information. The artificial neural network was trained and tested using real cases data and it was found very accurate results for the deltaic systems interpretation obtaining an important computational tool for professionals that work in geology area.

Key Words: Fluvial delta, artificial neural networks, Classification

1. Introduction
Any scientific and humanistic activity seeks to expand its range and knowledge to enhance their usefulness in activities related to their field. This expansion leads to interesting mergers between different disciplines that are complementary and supportive to yield results highly useful and sometimes even unimaginable. This work seeks one of those mergers that until a few years ago was almost unthinkable and that fortunately has been given for the sake of the earth sciences. The integration of computational methods relating to artificial intelligence and specifically the use of Artificial Neural Networks (ANN) [5, 6, 7, 15] as assistant tool for identifying specific sedimentary environments, in this case Deltas with fluvial domain [1, 8, 10, 11, 12, 13, 14]. Mostly river are recognized through Artificial Neural Networks giving input data that is processed by the system and recognized through responses that are faster than conventional identification methods of these sedimentary environments.

First is a brief description of the main sedimentary environments of the processes that lead to their formation and their characteristics. Then, it will be described the peculiarities of the deltaic systems dominated by river flow, which includes their characteristics, training and classification. Within this classification there is a brief review of other types of delta because of the close relationship between the two types of effects in cycle deltaic; also explains the characteristics of the lithological and paleontological facies that composed of two main types of river deltas domain, and in general petrological features. Followed is explained with respect to the beginnings of Artificial Intelligence and, in more detail defines the Artificial Neural Networks, the way they operate to deliver the expected results and its analogy with biological neural networks. The results of this work are discussed in a manner that is understood as the network trains with input patterns based on characteristics of formations identified by their origin riverine deltaic domain to be able to do the training and testing of the network with real cases. These procedures are carried out with the software named Propagator™ [15] and is shown in tables and graphs whose objective is the general understanding for seeing and using the software.

2. Methodology
The fulfillment of the objectives set forth in this work was carried out according to a specific methodology in order to solve a number of practical problems when defining an environment with greater influence of deltaic sediment river. The stages followed are:

2.1 Bibliographical Review
At this stage of data collection was performed theoretical underpinning research and can be
divided according to type of information in different media investigated both print and digital.

2.2 Background
Due to limited research that integrates data sedimentological and operation of Artificial Neural Networks, it was essential to make a review on the matter in order to understand the manner in which these two disciplines can be integrated. This information was found in final works of dree at Universidad de Los Andes [2, 3, 4].

- Geological Information Digest: First, it was collected information regarding sedimentary environment and their classification processes in order to use it for training and the general characteristics of these in terms of sedimentary structures, maturity and sorted. Then the bibliographic research focused on the deltaic environments, classification, development and general characteristics and then focus on the deltas dominated by the action river doing a detailed review of its characteristics in terms of lithology, composition, sedimentary structures, content paleontological, architecture sedimentary and, in general, all the characteristics that define these sedimentary environment.

- Information Relating to Artificial Neural Networks: This review was framed within the information about artificial intelligence. The Artificial Neural Networks were investigated from a theoretical point of view, about their history, application in various fields of science and technology and its theoretical bases of operation.

2.3 Parameters Generation for defining the Artificial Neural Networks Training
Once collected geological information, it was identified the systems characteristics with deltaic domain river known examples. During this review there were identified the characterization parameters of the environment under study.

- Training Model Design: At this stage, it was chosen the network model, the variables incorporated in the preprocessing of the information to shape the joint training. 
- Training Network: Once the neural network topology was selected it was followed the next steps:
  a) It was introduced the values of the input vector \( X_p = (X_{p1}, X_{p2}, \ldots, X_{pn})^T \) to the input layer.
  b) It is calculated the entry to the hidden layer neurons using the weighted sum functions and bias.
  c) It is generated values that are introduced into the activation function for calculating the hidden layers outputs.
  d) From the above calculation are derived values that join as input values in successive layers until it is reached the hidden layer output.
  e) Hidden layer outputs are introduced in the last activation function, in the output layer for obtaining the network output.
  f) Compared with a desired response it is calculated the error in the output layer.
  g) Then, it calculates the error in the hidden layers
  h) Then corrected weights of the output layer.
  i) It corrected the weights of the hidden layers.
  j) The process would be closed when the error is fairly minor.

- Neural Network Test: This was done by entering information from various sedimentary environments for checking the training effectiveness. The algorithm of the network is the same as the previous phase. Additional tests were conducted with a limited number of patterns for verifying the operation of the network.

2.4 Software Presentation
The proper training of the network led to the realization of a graphical user interface for this system to be used by users with expertise in sedimentology, in a simple presentation and easy understanding to assist in the interpretation of deltaic systems with river domain.

3. Systems Design
3.1 Designing artificial neural network:
- Defining data input:
  This section presents the parameters that follows the network for its recognition of learning environments riverine deltaic domain. The following parameters were chosen based on the Petrology characteristics, physical and paleontological sedimentologics of known cases.
  The items were coded based on the Miall (1996) [1] classification for facies associations and architectural elements in river systems, which have made modifications that adapt better to this code domain riverine deltaic systems. These are valued with +1 if a parameter characteristic of the environment, -1 absent and whether it should be zero (0) if a parameter is not absolutely reliable for their presence or absence. It is necessary to use in certain cases a question mark (?) To indicate the ignorance of the value of a variable.
  a) Architectural Elements
Distributaries Channels (CHd) in general tend to form channels straight with very low sinuosity, with a depth between 5 and 20 meters deep. The sediments found ranging from coarse sand and gravel, as load fund, arranged with very thin interbedded shale in the sands. The sequence is granodecreciente contacts with the abrupt and gradual basis towards the ceiling. In the sandstone can be presented stratification massive cross-stratification as well as predominant sedimentary structure, the shale is usually presented in laminations rolling. Due to be areas with high energy transport bioturbations not often seen, however it can be found common icnofacies as Planolites. Thin layers of coal are common in these channels.

Channels and bars Gravel (GB), the aggregate constitute a smaller percentage in the composition of deltas and are significant only in the distributary canals as load fund but their accumulation in bars significant within the environment does not happen Flow gravity sediments (SG), which occur in deposits with high slopes, mainly in rivers intertwined with beds of gravel. For riverine deltaic environments, the slope is lowest and therefore the presence of this element would be a negative indicator of the environment studied in this work.

Front deltaic and Mouth bars (SBD), is the area where they are deposited sediment load carried by the fund distributary canals so the percentage of sand is greater than 75% with a better choice toward the ceiling, are bodies upwarding. It is presented in parallel rolling shale and cross-stratification of high and low angle as if current ripples in the sand, just as there sinsedimentary deformations. The thickness varies from 2 to 9 meters and contacts can be gradual or abrupt as they can be cut by distributary canals through prodelta facies.

Downstream increased (DA), which is absent in deltaic environments of any kind. It is characteristic of rivers intertwined in which is also associated with accretion side.

Winger Increased (LA), this element is usually present. Each accretional unit is characterized by the gradual decrease of particle size in fastening systems ranging from litofacies gave up shale and mud.

Foil laminated sands (LS), the characteristic element of meander rivers environments that can affect the delta plain.

Erosion depression (OH), characterize anastomosade rivers environments.

Natural Levees (LV), which are dominated by shale over sands, rolling undulating latter, it also presents stratification and lenticular sinsedimentary structures. The contacts are abrupt top and bottom. The most important feature of these deposits is the inclination of about 15 in opposite directions.

Crevasse Channel (CR), are deposits of breakage during periods of increased flooding of channels, usually found in the delta plain associated with crevasse play.

Crevasse play (CS), there is a predominance of sand finingup with lenticular shale. The contacts are usually abrupt in base and top. Sedimentary structures are represented mostly by flat-rolled in sand and shale in undulating, as well as ripples or ripples marks. The thickness varies between 2 and 5 metres. It can preserve icnofacies type Planolites.

Deltaic plain and interdistributary Bays (FFD), which is dominated by shale with some interbedded sands forming environments marshes and swamps in sequences corasening upward very large surface but little thick (about 3 meters on average). Lenticular stratification is the most common sedimentary structures. There may be presence of siderite reddish or yellow. The bioturbation can be plentiful in areas more distant from the distributary chanel.

Abandoned Channels (CH(TF)d), they are characteristic of deltas with river domain and are filled with fine sand interbedded shale deposits forming gradually coming into contact with deposits of interdistributary bay. Sedimentary structure is the most common cross-planar stratification in two directions. The layers of coal are very common.

Prodelta (FP), is the area where most distal deposited mostly fine sediments (clay and silt) with low percentages of fine sand.

They tend to be less thick facies in the deltas river domain. There are parallel stratification and lenticular, stratification and cross ripples supply. The bioturbation shaped structures type burrow is abundant in areas of the distal prodelta.

Coal (C), this element refers to the existence of large coal thicknesses and not thin sheets. The development of coal can be given in the delta plain but also on flood plains of meandriform environments.

Evaporites (E), can occur in the areas of internal bays interdistributary but not a conclusive element for such environments.

b) Sorting: According to sub type of environment where they are sediments studied may vary significantly. In areas of distributary chanel, delta
front and overflow structures, sorting is generally low to moderate. In the facies where energy transport is lower like delta plain and prodelta, the sediments are more homogeneous and therefore there is a better sorting without becoming optimal. However, being an environment with high energy transport is apparent that the choice in general is low to moderate, but not a uniform pattern throughout the environment, not be taken as definitive and not to identify him will be given much weight as input from the network.

c) Textural Maturity: Like the previous parameter, textural maturity is a uncertain marker to identify deltaic environment with river domain, as it can vary greatly from one sub-environment to another for the great difference in energy transportation. But since this was high energy transportation environment the trend towards a higher degree of maturity by sediments reworking.

d) Paleontology content: Paleontological indicators are greatly important for determining any sedimentary environment so their presence or absence in deltas dominated by rivers are no exception. It has been reported that these environments are high-energy transport and even more calm areas are influenced by this factor in times of flooding. This will take into account several indicators.

Fossils Presence, which is low in these environments due to the strong influence river that does not allow the accumulation of fossils.

Shells remains, which are usually only used in the crests of the mouth bars by wave reworking. Their presence in proximal sub environments is none

Bioturbation, generally very low in delta areas, almost absent, except in distal zones when appear structures like burrows. They are the most abundant of the paleontological three indicators used as input parameters. The presence of icnogenerous Skolithos and Planolites as is common in certain areas of river deltas domain, but in areas with higher energy transport are weak or almost non-existent.

c) Composition: Over the river deltas domain, the composition is an excellent parameter for identification and differentiation between deltas. As a general feature the percentage distribution of gravel, sand and fine (clay and silt) is:

Gravel: 1 ≤ % < 5
Sands: % ≥ 75
Clay: 5 ≤ % < 25

f) Sinsedimentary Deformations: The high and rapid rate of sedimentation of the river deltas domain causes a variety of sinsedimentary structures that are highly useful identifying these environments and although there is no conclusive parameters. The main structures of this type for these environments are diapir mud, mudflows, landslides, collapse of depressions and charging structures.

g) Accessories Presence: It is generally founded in sandstone, constituting percentages of less than 2% and for the purposes of this study are listed and indexed as accessories pyrite, quartz and pebbles quite relevant siderite. The presence of minerals accessories is an element to take into account to classify deltas, but not conclusive for identification.

3.2 Output Definition
This network will identify two outings very well defined, as it assesses whether the studied area belongs or does not belong to a river delta domain. If the answer is yes is treated as (+1), if the answer is negative is treated as (-1).

3.3 Training Patterns definition
The investigation in different jobs, leads to parameters selection that serve as input and output variables to achieve training and testing pattern set of the neural network designed. Tables 1 and 2 show how it have been codified the variables that the user must choose to enter the information gathered.

3.4 Network Design
The type of network used in this work is a multilayer neural network with backpropagation learning algorithm. In this kind of networks, the information flow in one direction, with all its layers and interconnected operation are fully synchronous, indicating that deterministic methods are used in each cycle of learning to enable all units of a layer, thus diminishing the error by adjusting the weights.
Table 1. Neural network Inputs

<table>
<thead>
<tr>
<th>Arquitectonic Elements</th>
<th>Yes</th>
<th>No</th>
<th>?</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHd</td>
<td>+1</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>GB</td>
<td>-1</td>
<td>+1</td>
<td>0</td>
</tr>
<tr>
<td>SG</td>
<td>-1</td>
<td>+1</td>
<td>0</td>
</tr>
<tr>
<td>SBd</td>
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<td>-1</td>
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</tr>
<tr>
<td>DA</td>
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</tr>
<tr>
<td>LS</td>
<td>+1</td>
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</tr>
<tr>
<td>HO</td>
<td>-1</td>
<td>+1</td>
<td>0</td>
</tr>
<tr>
<td>LV</td>
<td>+1</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>CR</td>
<td>+1</td>
<td>-1</td>
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</tr>
<tr>
<td>CD</td>
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</tr>
<tr>
<td>FFd</td>
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<td>-1</td>
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<tr>
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</tr>
<tr>
<td>FP</td>
<td>+1</td>
<td>-1</td>
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</tr>
<tr>
<td>C</td>
<td>+1</td>
<td>-1</td>
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</tr>
<tr>
<td>E</td>
<td>+1</td>
<td>-1</td>
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<table>
<thead>
<tr>
<th>Textural Maturity</th>
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<tbody>
<tr>
<td>Maturity Level</td>
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<table>
<thead>
<tr>
<th>Paleonologic Content</th>
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<th>?</th>
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<tbody>
<tr>
<td>Fossils</td>
<td>-1</td>
<td>+1</td>
<td>0</td>
</tr>
<tr>
<td>Shell rests</td>
<td>-1</td>
<td>+1</td>
<td>0</td>
</tr>
<tr>
<td>Bioturbation</td>
<td>-1</td>
<td>+1</td>
<td>0</td>
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<table>
<thead>
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<th>Composition</th>
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<th>No</th>
<th>?</th>
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<tbody>
<tr>
<td>Gravel</td>
<td>+1</td>
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<td>0</td>
</tr>
<tr>
<td>Sands</td>
<td>-1</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>Clay</td>
<td>-1</td>
<td>+1</td>
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<tr>
<th>Sinsedimentary Deformations</th>
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<th>No</th>
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</thead>
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<tr>
<td>Sinsedimentary deformations presence</td>
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<table>
<thead>
<tr>
<th>Accessories Minerals</th>
<th>Yes</th>
<th>No</th>
<th>?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siderite</td>
<td>+1</td>
<td>-1</td>
<td>0</td>
</tr>
</tbody>
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Table 2. Neural network Output

<table>
<thead>
<tr>
<th>Output</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Deltaic environment with river domain</td>
<td>+1</td>
</tr>
<tr>
<td>Other</td>
<td>-1</td>
</tr>
</tbody>
</table>

- **Network Architecture:** The network consists of three layers: Input layer has 26 nodes (according to table 1), the hidden layer 26 nodes and the output layer 1 node, with linear activation function in the first layer, sigmoidal function in the second layer and hyperbolic tangent role in the output layer. The initial weights, by default, ranging from -1 to +1 being Generalized Delta learning rule used.

- **Training Parameters:** Learning rate was set at 0.005 because it must be low so that learning takes place more effectively, a high value can generate sharp changes in weights of variables with possible errors in learning. The momentum factor is a factor that weighs the range of changes in the weights for each cycle and was established with a value of 0.98, since this should be so theoretical between 0.95 and 1. As an initial range, were established 1000000 total training cycles, which can be expanded to seek a minor error training, which was established in at least 1x10^-7, with reports of error parameters each 10000 cycles. The file with the training patterns is obtained from real cases of river deltas domain.

- **Testing Parameters:** The file used for this stage have been developed from different patterns, first with information on work by Sanchez, E. et al (2006) [2] in Urdaneta Reservoir, Misoa Formation Zulia State, establishing a system of river deltaic domain as environment. The second was derived from data obtained from the Technical Report by PDVSA-INTEVEP and Pico. et al (2001) [3]sedimentological and bioestratigraphic analysis in cores, Oficina Formation in Anaco, Anzoategui State, which recognizes a deltaic system waves dominated. The last test pattern of the network was developed by taking the information contained in work Hernandez, M. et al (2006) [4] in Guafita Field southern Apure State, with characteristics of a deltaic system tides dominated.

- **Training:** The training of the network proved successful since it reached a training error below 1 x 10^-7, exactly 1 x 10^-8 in the cycle 999566, and an error test even lower with a value of 4.99654 x 10^-11.

3.5 Mathematical Model
The way the network operates is quite complex because of the variables number that are handled and the amount of existing connections. However, this section shows the equations that the network remains at its training period:
- **Input-Layer**: The 26 nodes layer is defined by the 26 variables displayed in table 1. It defines 729 $W_{ij}$ weights (including the bias $b=1$), where $i$ denotes the node and $j$ is the corresponding input. Then, it is calculated $Z_i$.

$$Z_i = \sum_{j=1}^{26} (W_{ij} \times X_j) + (W_{i27} \times b)$$

Where $i = 1, 2, \ldots, 26$

The calculation of the 26 outputs of this layer $Y_i$ uses $Z_i$, previously calculated, using the formula:

$$Y_i = (W_{i27} \times Z_i) + b$$

- **Hidden Layer**: The output from the previous layer is used as input in the hidden layer. So, the outputs of the hidden layer are calculated as follows:

$$\Psi_i = \frac{1}{1 + e^{-Y_i}}$$

Where $i = 1, 2, \ldots, 26$

- **Output Layer**: The outputs from the hidden layer are used to calculate the input of the last layer, with 27 weights an a node through:

$$Z_{27} = \sum (W_{i27} \times \Psi_i) + (W_{2727} \times b)$$

The unique output address to activation function (hyperbolic tangent), which yields the final output:

$$Y_{27} = \tanh(Z_{27})$$

The output of this function can assert +1 if the entered data belong to river system deltaic domain or -1 if other sedimentary environment.

4. **Conclusions**

- Computer tools implementation in sedimentology is successful because it can help to solve problems of interpretation in depositional environments. The artificial neural networks have proved to be an applicable tool in deltaic system river domain interpretation, using data derived almost exclusively from simple observation and analysis of the sedimentary sequences studied.

- Methodology developed by Miall (1996) [1] in river environments has been the basis of the interpretation of architectural elements for river dominated deltas because the similarities between both types of deposits. Input values were developed according to different characteristics based on the type of existing architectural elements and absent, choice in sand, textural maturity, paleontological content, composition or percentages of gravel, sand and clay, deformations and sedimentary minerals accessories especially siderite. These values input parameters were judged in various research papers prior to create a list of patterns of training and testing of the network, codifying the values characteristic of deltaic systems with domain river with +1, values not typical or non-existent with -1. And leaving in place a range of doubt as to whether or not the item judged as zero (0).

- The neural network was trained using backpropagation learning algorithm under conditions characteristic of this scheme. Thus emerged a network design based on its architecture, parameters training and test parameters. The elements that composed the network are three layers: Input, hidden and output, with 26 nodes for the first two and a node for the latest. The activation functions are linear for the input layer, sigmoidal for hidden layer and hyperbolic tangent to the output layer. The output of the network shows two possible answers numerical: +1 and -1. The positive response refers to data entered in the network correspond to a system with domain deltaic river, while the negative response means that this is in the presence of other sedimentary environments. It was created a graphical interface that allows display examples of deltaic systems dominated by rivers easily, using new software, originated from artificial neural networks to assist in Recognition and interpretation of sedimentary environment.

5. **References**
