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Automatic First Break Picking in Seismic Traces by Neural Network.

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Abstract

The first break picking is a manual task of seismic interpreters performed before many computational seismic processing, based in their geological and geophysical experience and interpretative criterions.
In this paper we propose an automatic approaches to this task, based in the apresentation of an artificial neural network architecture, that quest simulate the human visual system behavior in a decision problem form. The applicability, efficiency and limitations of this approach will be appraised in synthetic data obtained starting out from the ray theory .

INTRODUCTION

Several waves front are generated by artificial seismic sources. We have special interest on the ray path geometry of a particular wave front that spreads directly from the fire point until geophones position in surface, becoming the first representative signal of the wave arrivals in the resultant seismic trace. This particular event in a seismic trace obtained in a seismic prospecting is called *first break*, or in other words, it represents the necessary time for the direct wave to go through the distance between the seismic source and the geophones, with the characteristic velocity of the weathering zone (PŠENCIK, 1994).
The first break picking importance can be visualized through its direct application in several stages of seismic data processing, standing out the following:
The static corrections accomplishment processing.
The inversion problem of shallow seismic refraction data.
The determination of intervals velocities with the VSP, where the first break defines the layers velocities.
All of these applications have an automatic computational version, except the first break picking, which remains in a manual version, that still needs a direct human intervension.
In this paper we propose an automatic approach to this task, based in the presentation of an artificial neural network architecture, that quest simulates the human visual system behavior in a decision problem form. The applicability, efficiency and limitations of this approach will be appraised in synthetic data obtained starting out from the ray theory (CERVENY, 1977).

THE ARTIFICIAL NEURAL NETWORK

The feedforward multilayer artificial neural network, also called as multilayer perceptron, presents a typical architecture composed by layers, that are artificial neurons groups, disposed orderly in function of the direction of signal propagation in its interior (HAYKIN,1994). This kind of artificial neural network has been applied successfully to solve some difficult and diverse problems by training with the error back-propagation algorithm, that was developed for general models of connectionists systems, and it can be applied in artificial neural networks as a special case. It became the most popular neural network learning algorithm, starting from PARKER (1985) and RUMELHART & McCLELLAND (1986) studies.
Our principal interest involved with the behavior of multilayer perceptron can be established on the properties presented by this class of artificial neural networks, which showed that is possible to train efficiently multilayer perceptron with hidden layers, in a way to produce the approximation of any continuous function (HAYKIN, 1994).
In this section we will present our problem approach of automatic first break picking in a seismic trace as a decision problem form by means of a feedforward multilayer percepton training with the error back-propagation algorithm.
In the manual fashion, the seismic interpreter has to select among a finite group, composed by all the events registered in the seismic trace, one event relative to the first break, based in its experience and in the seismic traces interpretative criterions. This way, the characteristics requested for the visual system simulation of the seismic interpreter, through neural network are:
The seismic trace will be its only information source.
To locate in time or in depth, each first break position in each trace that composes the seismic section.
The simulation of the interpreter decision, based on the conception of a neural network with supervised learning, needs the interpreter interference for the training group definition, starting from the appropriate choice of a seismic trace groups, where he identifies the time or depth occurrence of first break events.
The neural network architecture project is, basically, composed by three stages:

- The definition of the number of computational layers and in the interconection way among them.
- The definition of neuron numbers in each layer and its respective activation functions.

The definition of training set.
To proceed, we described in details our neural network architecture for automatic first break picking.

- Input Layer

Here we take a seismic trace data as the only input signal of a feedforward neural network. For this task we interpret it from its own systematic acquisition, in this case, a stationary time series form. This seismic data interpretation simplifies its relationship with the neural network, so that it can be treated, formally, sample by sample (ANDRADE, 1997). In this manner, the time variable stops being intervening in the process.
That interpretation of seismic trace induced to the concept for the need of one input layer for neural network composed by one artificial neuron only. The existence of one neuron only in the input layer allows a good flexibility in the choice of training set size.
The first implication of this architecture is that training with error back-propagation algorithm allows the learning to be accomplished with the whole patterns at the same time, which results in a better determination of gradient direction (HAYKIN, 1994).

- Hidden Layer

To continue the neural network architecture, we determine the neuron numbers and, consequently, the hidden layer numbers. This definition depends, fundamentally, on the interpretation kind of the internal processing involved inside a neural network and the problem type which the network will operate.
Here we interpreted the neural network training with error back-propagation algorithm, in the universal function aproximator form. Thus, it established the need for one hidden layer only (HAYKIN, 1994).
The neuron numbers of this hidden layer is variable and it depends, fundamentally, of the seismic trace complexity. The approach adopted in this work, based on the accomplished experiments, was establishing the neurons number of the hidden layer equal the samples number of training set. That form allowed an appropriate training time with a good performance in the automatic first break picking operation phase.

The neurons in the hidden layer (Figure 1) present as activation function the logistic function or

$$y_k = \varphi(U_k) = \frac{1}{1+e^{-U_k}} \quad , \qquad (1)$$

where y_k represents the neuron *k* output and U_k represents the potential activation of the neuron *k* in the hidden layer, in the form

$$U_k = \sum_{i=1}^{N} w_{ik} \, x_k \quad , \qquad (2)$$

and w_{ik}, represents the synaptic weight between neuron *i*, in the input layer, and neuron *k*, in hidden layer. x_i is the neuron *i* input at any time.

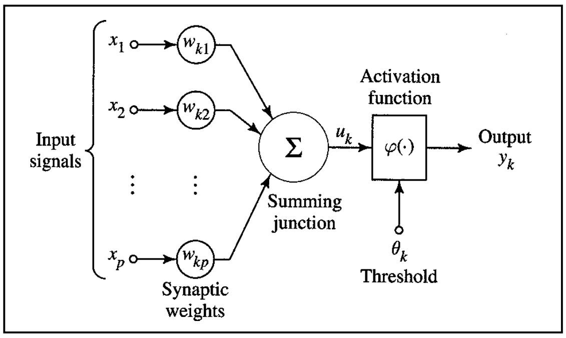

Figure 1: Artificial neuron in the hidden layer.

- Output Layer

The definition of the output layer starts in interpretation of simulation problem of seismic interpreter visual behavior for the first break determination in a decision problem form, that is, front to the event groups that form the seismic trace (reflections, multiples, first break, noises, etc...) the interpreter will decide with based on its experience if a certain event represents or not the arrival register of direct wave. In this manner, we have a classical binary decision problem, in others words, there are two possible alternatives: yes, for first break case and no, for all the other events.
This interpretation problem will enduce, in the project of neural network architecture, in the needs of one neuron only in its output layer, which means, it would be the direct association of binary characteristic answer of artificial neuron to the problem solution for a specialist. In this case, where the multilayer perceptron detects the first break, the output layer neuron will be activated, producing an output ideal signal like one. For all the other events, this neuron will be disabled and its output signal will be null.

- Training Set

We took the training set for the simulation of seismic interpreter visual decision for the first break picking in the seismic trace, with the following characteristics:
The stimulus set is formed by a group of seismic traces that presents first break and sequences of other seismics events. The first breaks characteristics that will form the stimulus set will be chosen by interpreter approaches.
The desired response set is created in a binary form, which the value 1 (one) indicates the first break presence and the value 0 (zero), on the other hand. The definition of first break position in desired response vector, can be accomplished in agreement with seismic interpreter empiric knowledge.

RESULTS

We present an application of our approach to perform an automatic first break picking in a synthetic seismogran obtained from ray theory, shown in Figure 2, where the visual identification of first arrivals is a very easy

task, since the first break is characterized by a straigth line close to seismogram top. For this task, the interpreter only needs to adapt his visual system to change in position and amplitude the first break wave form characteristc for each trace that compose the seismogram. After this, he needs to read the first break time for each trace to complete his work.
In our approach to automatic first break picking, the interpreter only needs to indetify the time of the first arrivals in a few traces (two, at least) to produce the training set, that wil be used in the neural network learning phase. In this application, we used the first and second trace to produce the complete training set. The learning phase in a RISC/6000 plataform takes only a few seconds and the neural network is able to perform this work for the remaining traces.
The neural network computer results can be seen in Figure 3, that shows a seismogran like one seen in Figure 2, but now just the first breaks appear. This is an only graphical form to present the results of the neural network calculations, where the first breaks are marked by spikes .Another way is a table form, containing the trace numbers and the first break time. It is easy to see the good job produced by neural network. Afterwards, any computational process with seismic section can be performed in an automatic way.

CONCLUSIONS

The results obtained with this artificial neural network architeture for first break picking over synthetic data stimulate us to continue this research in the computational laboratory of the Curso de Pós-Graduação em Geofísica (CPGf). The next step of our work is to refine the neural network architecture to handle with real data and keep testing, with it and other artificial neural network classes, to seismic and well log data processing.

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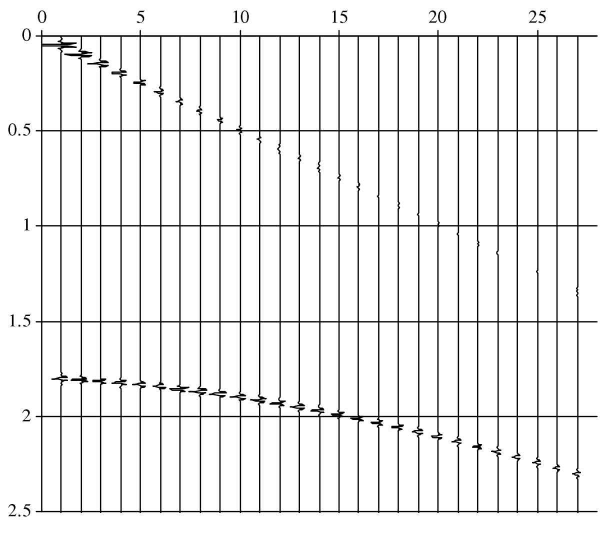

Figure 2: Synthetic seismic section, shown the first breaks close to top and a reflector at botton.

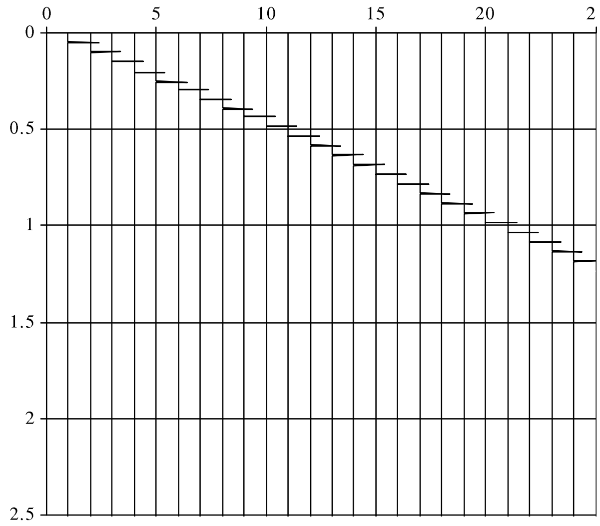

Figure 3: Seismic section shown the automatic first break picking performed by artificial neural network.