Tech Mahindra

EVALUATING THE QUALITY OF SEISMIC DATA: History and Trends

Whitepaper

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Connected Experiences.

Abstract

The oil industry relies heavily on seismic data for furthering its exploration efforts. The quality and volume of seismic data have increased tremendously in the last few decades and the trend still continues. Managing the quality of this data is becoming a challenge for the oil companies and now automation has to lead the effort. Machine learning is not new to seismics. Classifiers and discriminators have been in use since the 1960s. Of late the industry is showing keen interest in using Deep Learning to draw insights from the data.

Key takeaways

Reduction in TCO

- Remove or reduce the warehouse charges
- Increase the monetary value of the data packages
- Effort saved to access good quality data

Provide exploration leads

- Identify data gaps in acreages
- Enthuse renewed interest in old acreages
- improve the quality by reacquiring or reprocessing

Overall the benefit to the Oil & Gas companies can be anywhere between 5 to 10 million USD per survey

1. Introduction

Exploration of oil and gas started with the drilling of the first well in 1859, at Titusville, Pennsylvania. Till the turn of the century, this was more of a clairvoyant effort with a little scientific approach. However, with the use of logs by the Schlumberger brothers and the knowledge from the mining industry, things were getting to be a bit more organized. Prospectors were guided more by surface seeps to identify areas good for drilling. The first two decades of the 20th century evidenced such efforts in various parts of the world. Once all the surface seeps were identified and prospected, a need arose to better image the subsurface and the prospectors then turned to Geophysical methods of survey.

Fig. 1 First reflection survey

Seismic Survey is one of the geophysical methods that got into prominence in the 1930s. Although knowledge about seismic existed due to the study of earthquakes they were all passive studies. Then came WW-I (World War 1) and great progress was made inaccurately triangulating enemy artillery positions by measuring ground vibrations and noise booms.

After the war geophysicists turned that thought into practice at Oklahoma (Fig. 1). There the first reflection seismic was carried out in 1921 and the world has never looked back ever since. Interpretation of geologic features and inference of reservoir properties are necessary to the success of oil and gas exploration and production efforts. Often the processes involved in extracting useful subsurface information from seismic data are labor-intensive, time-consuming, subjective, and computationally demanding.

Seismic surveys are always ahead of its times by a factor of 1000. When the industry was talking about kilobytes, seismic was in megabytes. Even today when most of the industry uses data in terabytes, the seismic volumes are in petabytes.

2. Seismic data quality

A discussion of seismic data quality necessarily begins by defining exactly what is meant by "quality." In its most general sense, quality is the degree to which something fulfills its intended purpose. All measures of seismic data quality are inherently subjective, so it is important to know why a particular data set was acquired and processed the way it was, so as to set the proper context for assessing its quality. The seismic data maturity moves through 3 stages.

- Acquisition
- Processing
- Interpretation

Much of the focus on seismic data quality is concentrated on the latter two stages as their turnaround time is less. Also, the domain is restricted mainly to geosciences, computers, and IT Industries. Improving the quality of seismic field data requires better instrumentation, communication, onboard computing, etc., and other technological and scientific improvements. These are adopted depending on the cost-benefit analysis.

So, at first look, the field data should be "pleasing to the eye". This is entirely subjective. Here is where cognitive thinking starts in 4D. The fourth dimension here is time.

2.1 Attributes

Smooth continuous reflections clearly depicting the subsurface lithology and strong abrupt terminations for faults and other discontinuities make up good seismic data.

In Data Quality terms some of this can be enumerated as the following attributes

- Signal to Noise Ratio (S/N)
- Amplitude
- Phase
- Frequency
- Convolution (Smoothness / Spikiness)
- Coherency (Continuity)
- Dead traces – blanks
- Muted Data (Processing results)
- Artifacts (Fidelity)
- Clarity (Resolution)

Let us look at the images below.

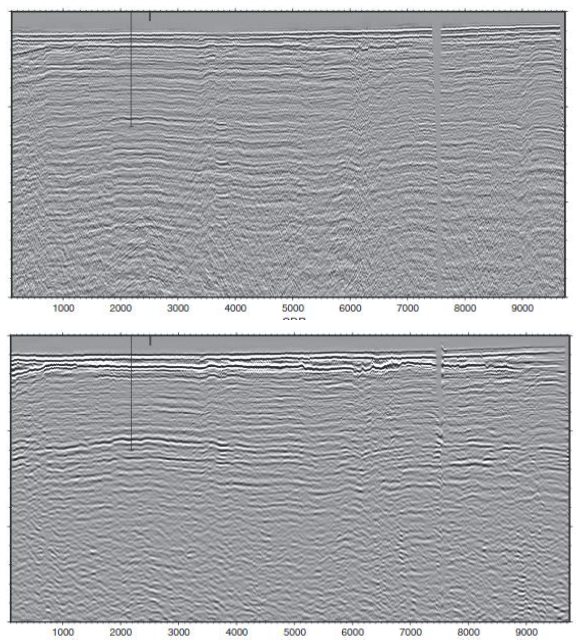
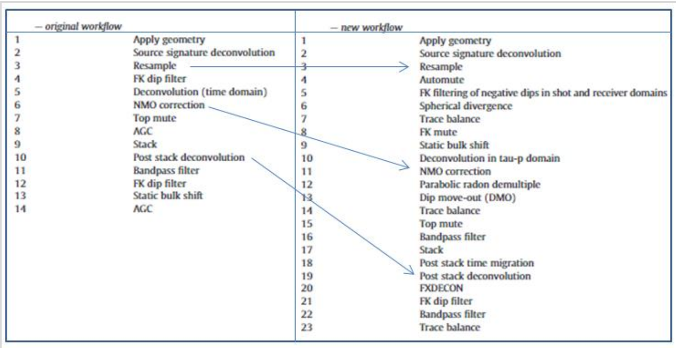


Fig. 2 Raw and processed data

To the discerning eye (Figure 2) it is obvious that the quality of seismic data in the second image is better than the first. This is thanks to advanced processing that is very complex. The challenge is how to train the computer to achieve the cognitive capability to put a quality index score with confidence. Old and new processing workflows of a sample survey are given below in Figures 3 and 4 to better explain the complexity.



original workflow		new workflow	
1	Apply geometry	1	Apply geometry
2	Source signature deconvolution	2	Source signature deconvolution
3	Resample	3	Resample
4	FK dip filter	4	Automute
5	Deconvolution (time domain)	5	FK filtering of negative dips in shot and receiver domains
6	NMO correction	6	Spherical divergence
7	Top mute	7	Trace balance
8	AGC	8	FK mute
9	Stack	9	Static bulk shift
10	Post stack deconvolution	10	Deconvolution in tau-p domain
11	Bandpass filter	11	NMO correction
12	FK dip filter	12	Parabolic radon demultiple
13	Static bulk shift	13	Dip move-out (DMO)
14	AGC	14	Trace balance
		15	Top mute
		16	Bandpass filter
		17	Stack
		18	Post stack time migration
		19	Post stack deconvolution
		20	FXDECON
		21	FK dip filter
		22	Bandpass filter
		23	Trace balance

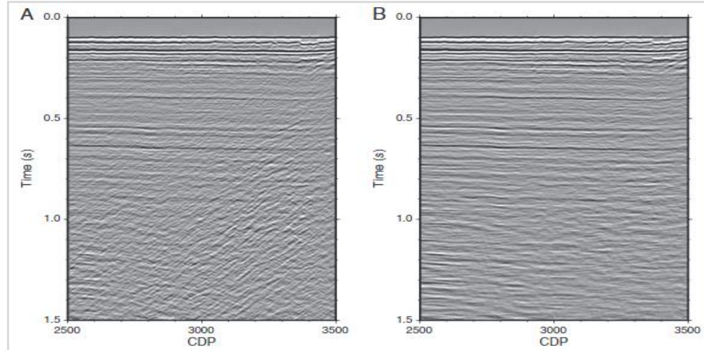


Fig. 3,4 Complexity in processing seismic data

So, although the improvement in quality is due to enhanced processing techniques, one has to realize that the assessment of this improvement is visual.

3. The Application of AI in Seismic

The application of artificial intelligence (AI) methods particularly machine learning (ML) is not new to seismic. The use of statistical classifiers has been in practice since the 1960s. But they have had limited scope and success. As explained above many simple and complex attributes (features) can be easily derived from raw seismic data. Before getting into the details of Deep Learning, let us understand the broader picture.

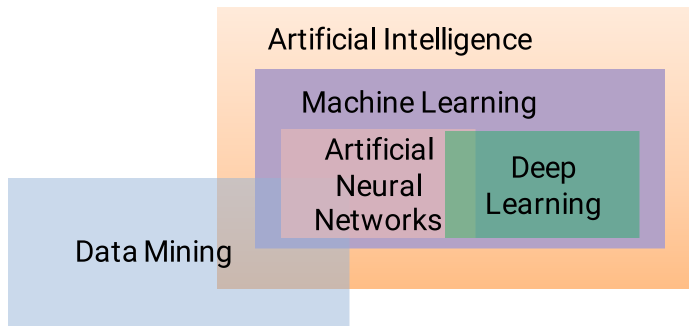


Fig. 5 Deep Learning

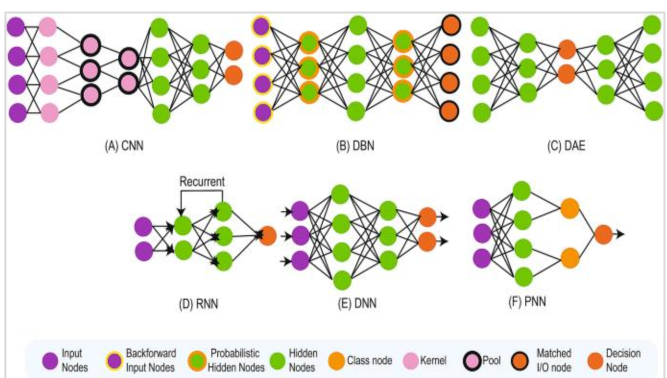


Fig. 6 Deep Learning Architectures

The figure above sets the context of Deep Learning vis a vis AI and ML. Deep learning is a special subset of Machine Learning (ML) using Artificial Neural Networks (ANN). Conventional machine learning methods tend to succumb to environmental changes whereas deep learning adapts to these changes by constant feedback and improves the model. Deep Learning (DL) is facilitated by ANNs which mimic the neurons in the human brain and embeds multiple-layer architecture (few visible and few hidden). It is an advanced form of ML which collects data, learns from it, and optimizes the model.

3.1 Tech Architectures

DL architectures are convolutional neural networks (CNN), deep belief networks (DBN), deep auto encoders (DAE), recurrent neural networks (RNN), deep neural networks (DNN), and probabilistic neural network (PNN). Figure 6 gives the details of each architecture.

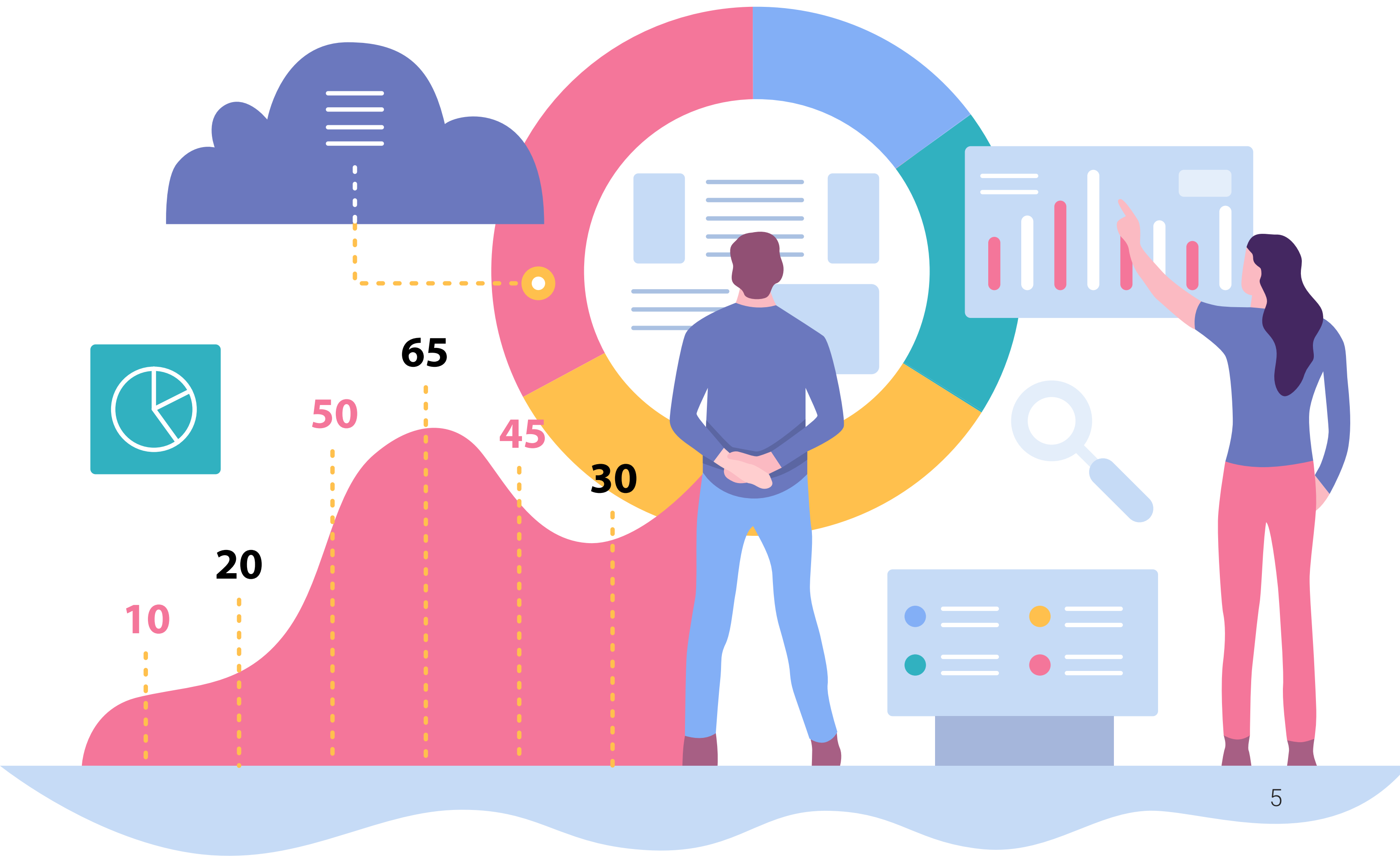
In recent years CNNs have been used to derive classical probabilities from seismic data. But their success and application areas have been very limited.

3.2 Challenges Ahead

Despite the power of CNNs, these nets have one drawback. Since they are a supervised learning method, they require a large set of labeled data for training, which can be challenging to obtain in seismic domain.

The Way Forward

- Traditional method of assessing seismic data quality involves loading the data onto a workstation and visualizing it.
- This in itself is a complicated and arduous task particularly if there are complications in the data set, typically in old data sets with missing navigation and support data.
- Recent advances and technological breakthroughs have allowed AI to be effectively used for seismic. But the emphasis in the industry is more towards automation of interpretation and processing tasks.
- DL can draw insights from the seismic data in its native format, without the need for costly infrastructure and HPC machines.
- This will create savings in time, effort, and license fees for interpretation software for the geosciences community.



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