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Unsupervised AI integration toward an efficient timeline reduction in a successful CCUS planning and monitoring process.

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Summary

Seismic data remains a pillar of subsurface modeling and the understanding of the potential for transitioning from oil and gas exploration to CCUS development planning and execution. However, interpretation is a biased and time-consuming process forcing geoscientists to spend more energy picking horizons and building models than interpreting the significance of the results and their implications for CCUS development.
In this paper, we detail the use of a new unsupervised Artificial Intelligence based on genetic algorithm to automatically process the seismic data in an unbiased way and record time.
After 12 minutes of AI processing, we could display all horizons on the seismic and visualize multiple attributes for all subsurface layers and start building all necessary geological model to evaluate the wells program and to de-risk key uncertainties for the project.
After project start up, 4D seismic is necessary for monitoring CO_2 containment and CO_2 plume migration. By the nature of the unsupervised and fast nature of this algorithm, we can apply this workflow to each 4D baseline and monitors, including all angle stacks in a record time and with an identical non subjective interpretation accuracy.
We will demonstrate the method and results over an Atlantic East coast area with high potential for a CCUS successful development.

Theory and Method

The key initial factor within those energy transition projects will be the understanding and integration of a huge amount of data available after so many years of Gas exploration and production and target a different focus workflow and reasoning with the objectives of ultimate CCUS project evaluation in mind. The traditional seismic data "interpretation" approach which basically refers to human intervention to pick horizons or analyze the seismic images obtained over the years could be an issue with the introduction of bias, the time required to process and analyze the data and finally the lack of accuracy.
On the contrary, the AI system described below, is global, fully automatic, and unbiased. The extraction of geological features (e.g., horizons) from seismic data can be seen as a data segmentation problem where the objective is to split the whole into the most coherent parts. Among the many AI algorithms, the genetic algorithm proved to be robust and very well adapted to the seismic data analysis. (Figure 1).

• An individual is a location in the volume characterized by the neighboring seismic waveform (the chromosome). Each waveform is characterized by its own unique suite of attributes (i.e., location, amplitude value, neighbor trace shape, etc.),

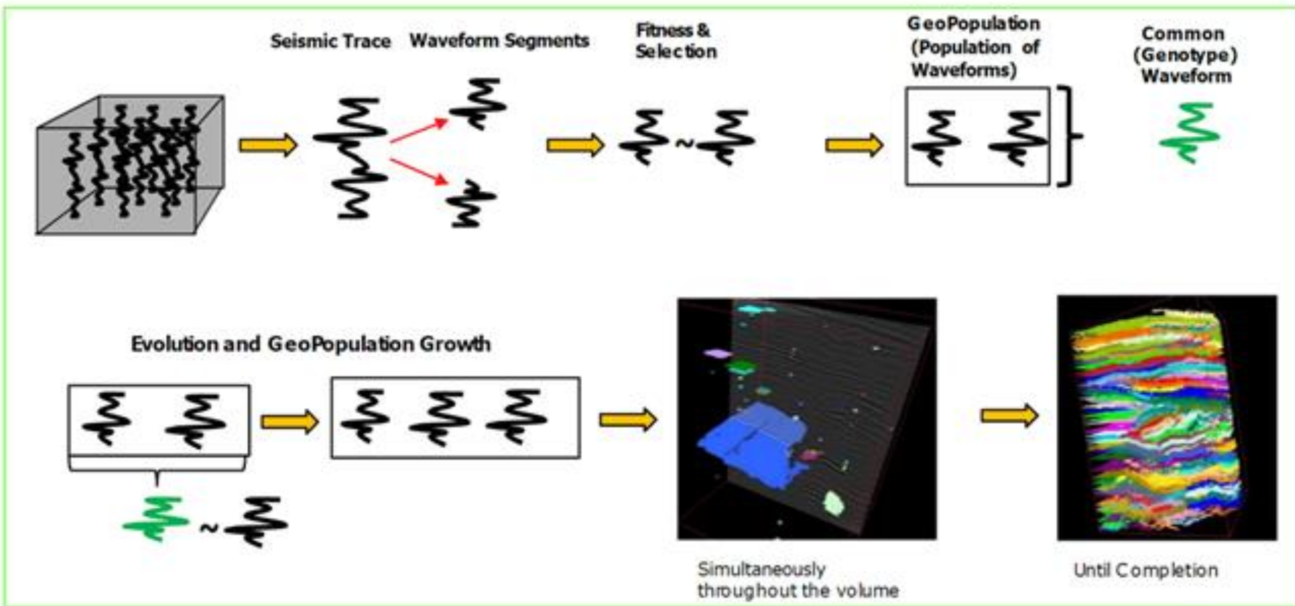


Figure 1 Unsupervised AI workflow based on Genetic algorithm.

• The population is the set all the individuals as all the locations in the entire seismic volume,
• A sub-population is a group of individuals (a seismic horizon) that have the maximal genetic similarity (maximal waveform similarity).

The purpose of the GA is to mimic the genetic process of biological evolution based on the "survival of the fittest" principle applied to the seismic samples to produce the optimal "sub-populations" i.e., the horizons. The seismic volume is represented as a population of individuals that must be grouped into horizons throughout the process of the biological evolution. Therefore, at every generation:

The selection - only the fittest: individuals and sub-populations that have the highest fitness (seismic similarity) are allowed to evolve. The selection is in favor of cohesion: it tends to bring together those seismic waveforms that constitute the most "balanced" horizons,

The crossover: the selected individuals and sub-populations combine their genetic information to build a new generation. The combination tends to straighten the contribution of some seismic character and therefore to maximize the intra-sub-population similarity and maximize inter- sub-population dissimilarity.

The evolution continues throughout the entire volume until all the sub-populations have been identified, characterized, and categorized into a database of horizons ready for analysis.

Workflow and results

We developed a 7 steps workflow to go through the input database to the technical and economical project viability analysis.

The utilization of the AI approach in the front end reduces the time spent clicking and manually interpreting during the first 2 steps, allowing us to have more time focusing on understanding the results and the key uncertainties and risks. (Figure 2).

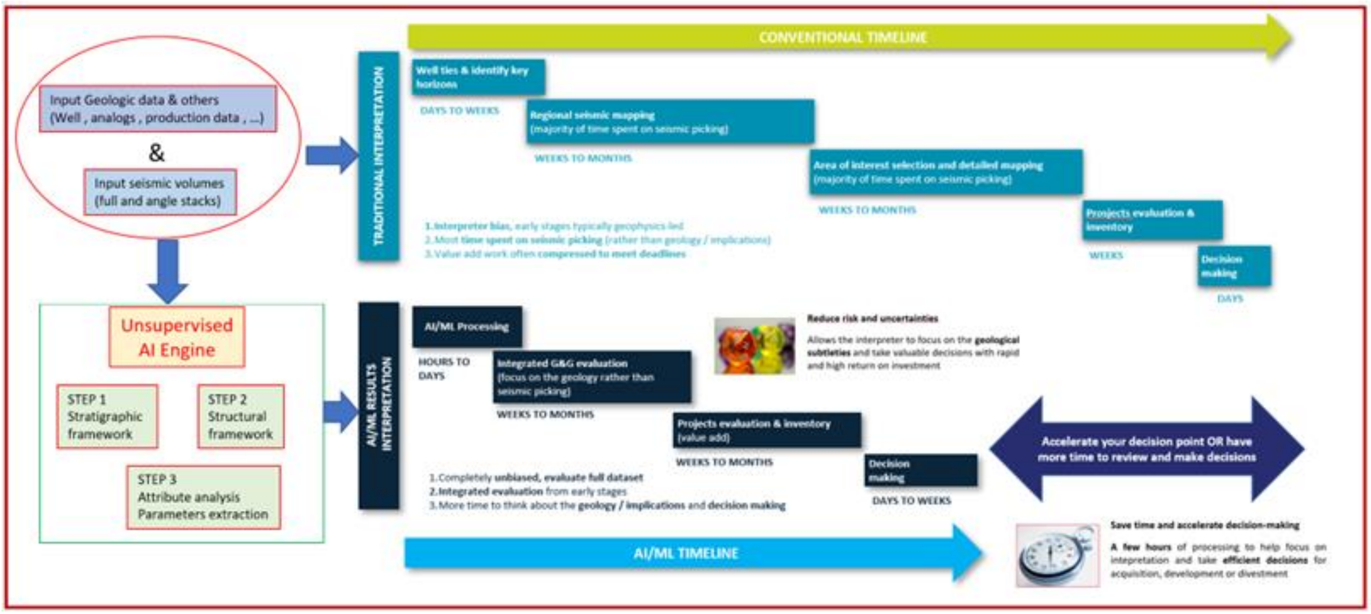


Figure 2 Unsupervised AI versus traditional workflow timeline

Step 1.

Seismic volumes were downloaded in SEGY format and were directly processed without any additional treatment, by the GA in less than 12 minutes for each dataset.

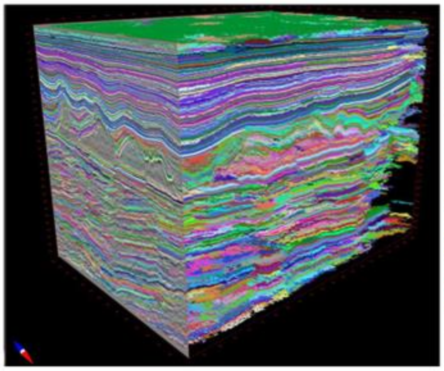
Seis-H pr-interpretation analysis is fully automated and is applied consistently through the all-seismic datasets, thus producing a database of unbiased and high-quality attributes Seis-H extracts almost every peak and trough surfaces allowing 100% of the seismic data to be examined, meaning previously underexplored and potentially missed features can be analyzed.

A total of 2477 horizons have been automatically computed by the AI with different continuities over the seismic volumes. The surfaces, their specific waveform and their associated attribute maps are integrated into an easily accessible visual database through an interactive visualization software. (Figure 3).

Step 2.

Seis-F the fault extraction application is completely unsupervised and only data driven based on the seismic data and the surface database from Seis-H and does not require any questionable learning or the step backwards manual labelling. It extracts almost every fault plane objects from the seismic volume by going beyond detection of simple discontinuities on the seismic image and searching for planar breaks in the geological layers database built with Seis-H.

Seis-F extracts first all fault polygons which are defined by its geometry and a throw map. Secondly Seis-F group them into fault planes considering the fault polygons properties, geometries, throw maps and the underlying seismic data. (Figure 4).



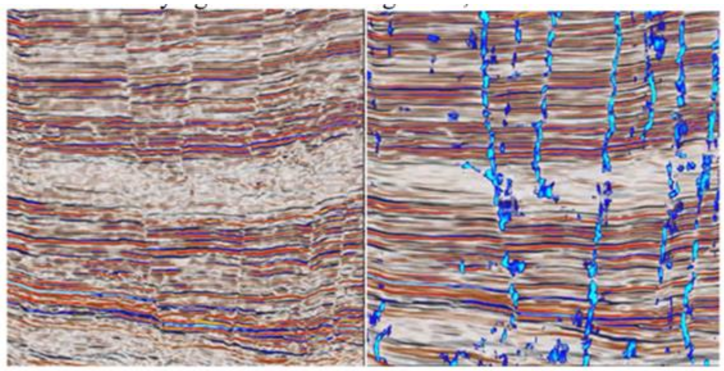


Figure 3 2477 Geo-populations identified within the Full stack seismic volume.

Figure 4 250 Faults with probabilistic value extracted from the volume.

Step 3.
The interactive and query able database of surfaces and faults with their own suite of attributes allows for the rapid screening of the data and bring to light any viable and prospective areas.
Each surface is characterized by their waveform genomes, and we can build seismic facies maps through sub-waveform analysis and identify stratigraphic domain within all datasets including unconformities, stratigraphic trap, seal, and reservoir units.
In addition, the fault polygons properties are used to identify structural domain within the datasets.
Subtle features both stratigraphic and structural are automatically identify and characterized within the resulting database.

Step 4.
We built this unbiased database of surfaces, fault planes, seismic facies, and stratigraphic/structural domains in less than one day for the complete seismic volumes (Surface to about 5000m).
This database allows us to spend our time analyzing the data and integrating the geologic data base including 45 wells, outcrops, production history and previous studies.
The well ties and rock physics model help us to link waveform and attributes for all key surface/faults to essential geological properties and quickly establish their spatial distributions.

Step 5.
The interpretation and integration of all geological / geophysical data provide us the tools to build an extensive portfolio of opportunities with relative ranking based on potential values and uncertainties.
After technical and economical screening of this portfolio, we can identify a large variety of viable prospective area for CO_2 storage. (Figure 5).

Step 6.
For each identified potential areas, we can quickly build the geological model necessary for full evaluation.

The key zones surfaces and main faults that will influence the flow are easily selected from our database, cleaned, and integrated in an airtight framework.
The model is then populated with any sub-zones layers and subtle structural features pertinent to our projects, quickly picked from the Seis-H and Seis-F databases. Lastly, we add the corresponding properties extracted from our extensive attributes database calibrated to wells and outcrops. This all process is done in less than a day as each element were built by our AI approach into a query able database for the entire data volumes.
In this final step of the CCUS project evaluation, we proceed the full technical, reservoir engineering, drilling and economical project and portfolio analysis based on the developed geological and reservoir models.
With a fast turnaround to build and eventually recycle those models, we have more time to integrate, interact with the larger team of experts and perform a sounds economical evaluation.

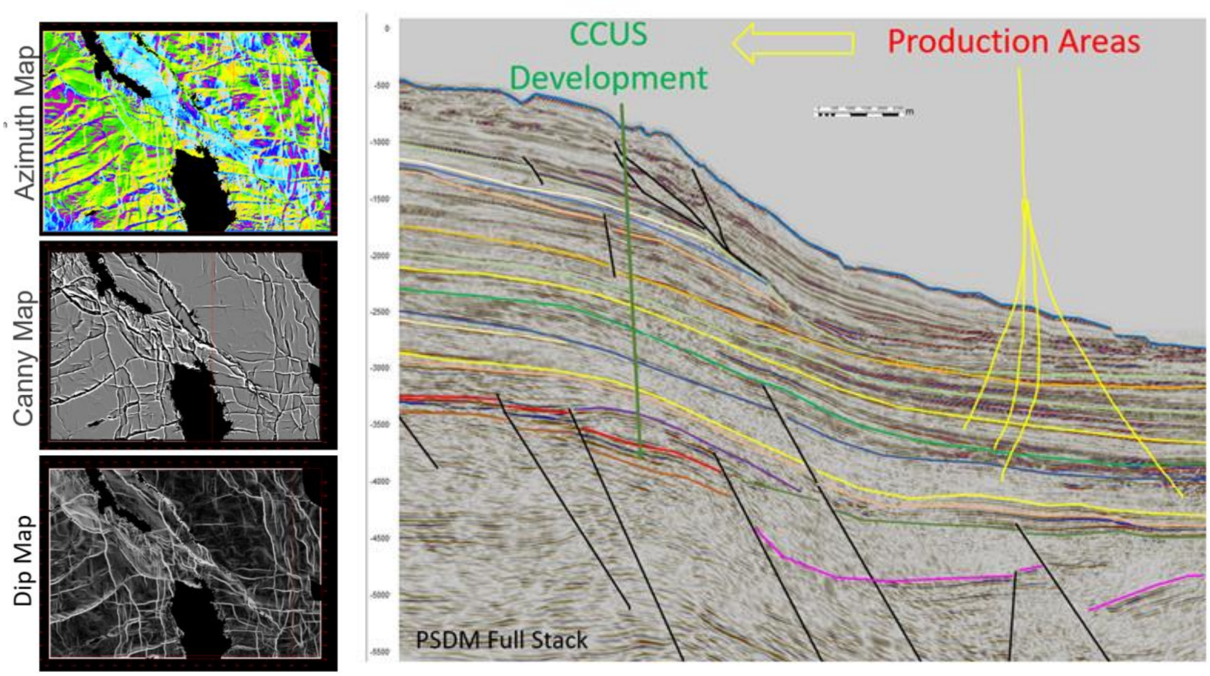


Figure 5 Selected location for the CCUS project with key attribute to de-risk the potential storage

Step 7.

CO2 sequestration in reservoir stipulate incorporation of comprehensive and innovative monitoring technologies. 4D time-lapse seismic is sine qua non for Monitoring, Measurement and Verification (MMV) planning to demonstrate the migration of CO2 plume within geological storage.

An ingenious, adaptive integration of the unsupervised AI workflow into the MMV plan for monitoring CO2 plume is paramount to minimize possible subsurface and project integrity risks. This process reduced the timeline and increase repeatability accuracy in building all necessary geological model toward integration of dynamic simulation with seismic forward modeling and significantly increase the capabilities of 4D seismic in CO2 sequestration projects.

Novel and conclusions

An artificial Intelligence based on genetic algorithm (GA) has been used successfully to automatically compute an extensive horizons/faults/attributes database.

After a processing step which lasted less than 12 minutes for each seismic volume, maps with various attributes were displayed for all the layers computed by the AI including amplitude for instance. Main faults planes and subtle features were also extracted and integrated into a database with their own properties and fault throw maps.
The genetic algorithm automatically generated a suites of e waveform, attributes and other characterization of surfaces and faults that help build stratigraphic /structural domain and seismic facies maps within the entire potential area top to bottom in less than a day.
Such an automatic, extremely fast, and unbiased approach can help the geoscientists directly focus their time and attention visualizing and interpreting the significance of the results delivered by the artificial intelligence for various applications.

References

Dirstein J.K., Fallon G.N., 2011. Automated interpretation of 3D seismic data using genetic algorithms. Preview, 2011:151, 30-37. doi: 10.1071/PVv2011n151p30.