Abrindo a boca do Jacare com Earth Intelligence®

Luc Sandjivy Earth Resource Management Services

Summary

Earth Intelligence® (EI) is Artificial Intelligence applied to geomodelling of O&G reservoirs. It allows for optimizing the parametrization of geomodelling workflows and automating them, thanks to minimizing a unique “cost function” that is the “estimation error”. EI probabilistic workflows best valorize seismic and well DATA available at the time of making reservoir E&P decisions. It unifies deterministic building of alternative scenarios as one single consistent P10 P50 P90 stochastic scenario.

Introduction

I remember having lunch in 2012 in Rio with Paolo Johann, Gerente de Geofísica de Reservatorios at Petrobras, and discussing how best to open Jacare's mouth, i.e., to provide E&P reservoir decision-makers with realistic low-, mid-, and high- geomodel cases in one go.

At the time, I was working on automating and optimizing depth conversion and velocity model building using Bayesian co-Kriging algorithms. It took me 10 years and the advent of artificial intelligence techniques in geophysics to understand that "kriging" based algorithms were the key to consistently automating geomodeling workflows and best supporting E&P reservoir decision makers with reliable P10 P50 P90 mathematical scenarios calculated in one shot.

Quantifying UNCERTAINTY attached to seismic and well DATA et consistently propagating it to GEOMODEL building would indeed enable to link all successive steps of geomodelling workflows and solve the Uncertainty issues face by reservoir decision makers, that is answering Paolo’ request : “abrir a boca do Jacare”. I then coined the term of “Earth Intelligence®” to differentiate “kriging” based ML algos from others (like NN algos) that do not specifically address the geomodel uncertainty issues.

After recalling how uncertainty works in the life cycle of E&P asset decision making, I introduce and more precisely define the term of “Earth Intelligence”, before giving an example of application in solving E&P reservoir structural issues.

O&G reservoir management :

About Uncertainty

At the time of making decisions, OPERATORS (O) always face UNCERTAINTY (U) because the available DATA (D) never fully represent the actual RESOURCE (R).

This is Uncertainty on DATA figured as the DO axis (DATA / OPERATION) on the UDOMoRe diagram.

To compensate for the lack and inaccuracy of DATA, OPERATORS (O) need MODELS (Mo) to support decision making. Because of Uncertainty, MODELS never fully equal actual reservoir.

This is Uncertainty on MODEL figured as The MoRe axis (MODEL / RESOURCE) on the UDO MoRe diagram

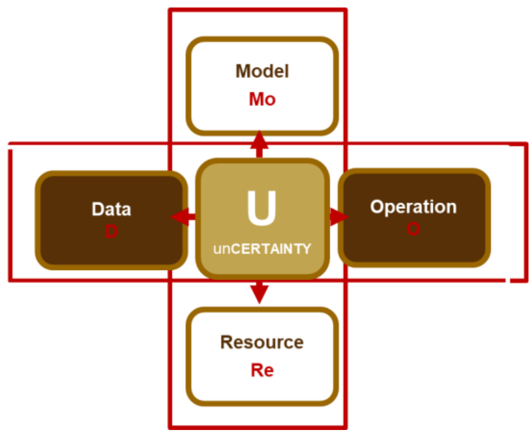

Figure 1 – The UDOMORE diagram

Uncertainty Economical Issue

Because of UNCERTAINTY, there is an inevitable gap between EXPECTED values made from MODELS and RESULTING values obtained after drilling actual RESERVOIRS.

RESULTING decision KPI s (Exploration success, Production plans, Reserve estimates…) are always lower than IDEAL KPIs that would have been obtained in the ideal but unrealistic case of no UNCERTAINTY.

UNCERTAINTY always means a loss in terms of project ECONOMICAL value

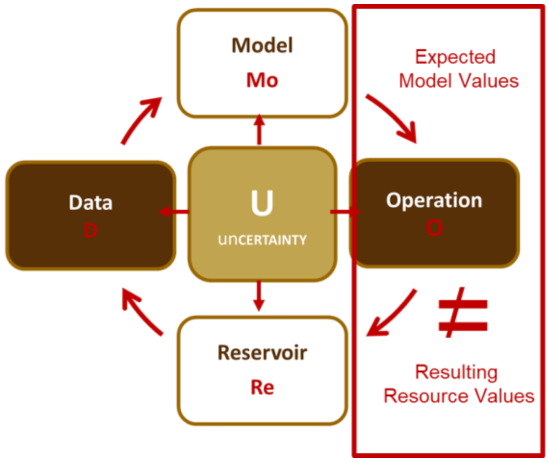

Figure 2 – The Uncertainty Issue

Uncertainty technical challenge

The Uncertainty technical challenge is fourfold:

1/ Quantifying Uncertainty on DATA, that is the measurement and/or Processing errors

2/ Consistently Propagating Uncertainty on DATA and when quantifying Uncertainty on MODEL

3/ Anticipating and minimizing negative impact of Uncertainty on the project economical value.

4/ Validating Uncertainty Quantification after drilling

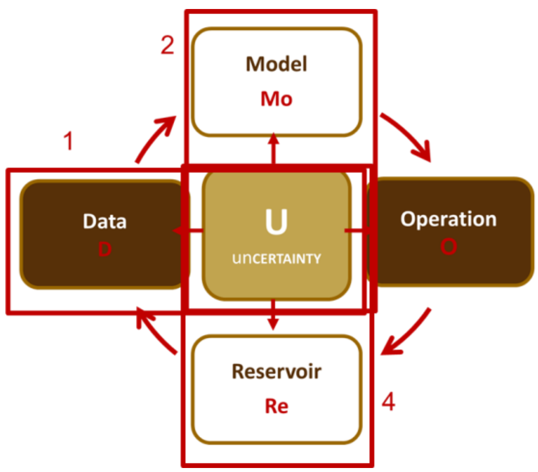

Figure 3 – The Uncertainty Challenge

Earth Intelligence® for addressing the Uncertainty technical challenge and best solving the Uncertainty economical issue

Earth Intelligence® is Artificial Intelligence applied to geo data (data with coordinates)

It is based on mathematical “Kriging” Regionalized Variable Theory (G. Matheron Paris School of Mines 1970)

It considers Uncertainty (estimation error) as the unique and specific "loss or cost function" to be minimized throughout the steps of the geomodeling process.

Minimization of estimation errors in the framework of probability models is the very definition of “kriging” algorithms.

Earth Intelligence Machine Learning algorithms allow for choosing the relevant probability model to solve the uncertainty issue.

They include a full set of spatial statistics, kriging & ensemble-based algorithms such as:

- Non stationary modeling for spatial trend residual decomposition
- Factorial kriging for Data conditioning
- Non-Stationary Bayesian Co Kriging for depth conversion
- Conditional simulations for GRV computations

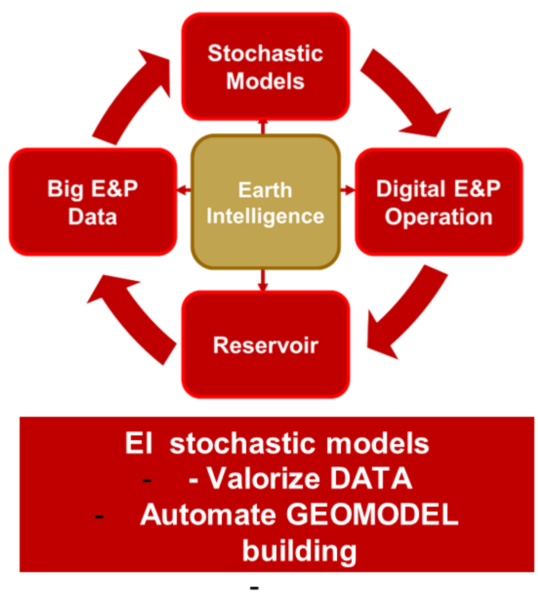

Figure 4– At the digital age, Earth Intelligence best solves the Uncertainty Issue

EI ML algorithms allows for:

- Automating GEOMODELING workflows
- Best valorizing the full set of available DATA
- Unifying deterministic building of alternative SCENARIOS as one single consistent P10 P50 P90 STOCHASTIC SCENARIO

Digital O&G reservoir management

Digital reservoir management means the ability to replace "black box numerical geomodels" by smart "digital reservoir twins" that in near real time :

- Best valorize the in real time the full set of available DATA at the time of decision making
- Best support the decision making with reliable P10 P50 P90 confidence intervals and corresponding geomodels.

As current geomodeling software are unable to do so, specific EI software platforms must be developed as EI "engines" to be plugged in existing data management and visualization platforms.

The UDOMORE platform developed by Seisquare company is a first example of such EI software for solving structural modeling issues. (See Figures 5&6 at the end of abstract).

EI platforms enable to build EI SCENARIOS that can be easily traced, shared, stored, retrieved and updated with new DATA.

EI SCENARIO includes DATA + STOCHASTIC WORKFLOW (see figure 5)

EI SCENARIO can be run in real time on any connected modeling platform

EI SCENARIO replaces "Blackbox numerical models" by "Smart Digital Twins" as shown in Figure 6.

A North Sea case study:

The case study describes how the interpretation from two partially overlapping seismic surveys is combined to produce consistent structural depth twins of key horizons with reliable confidence intervals.

Step 1: Assessment of seismic data qualification

Step 1_0: SQA of pre stack amplitude gathers

Perform a spatial data assessment (SQA) on the amplitude gathers used for stacking to calculate spatial quality indices (SQI) attached to the stacked amplitudes. These SQIs are used in the calculation of the picking uncertainty to be input to the stochastic depth conversion.

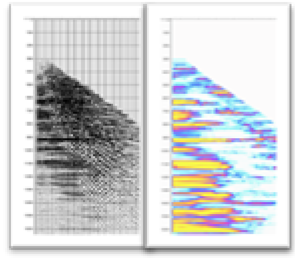

Figure 7– Computation of SQI on pre stack gathers. white blue: low confidence yellow red high confidence

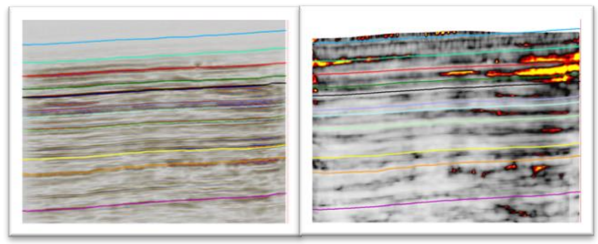

Figure 8– Computation of SQI on stacked amplitudes. white good confidence yellow red low confidence

Step 1_1: SQA/SDC of 2D depth/time interpretation grids

Perform Spatial Data Conditioning (SDC) on 2D time interpreted grids in order to produce optimized time interpreted grids, to be input to depth conversion Step 2

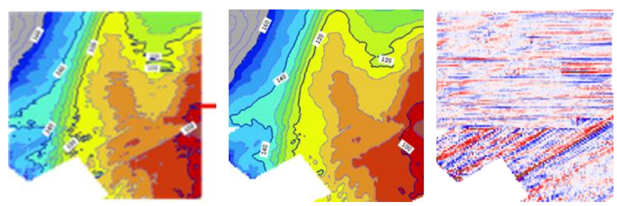

Figure 9– Spatial conditioning of interpretations (spatial artefact removal) optimizing the calibration to the wells

Step 1_2: SQA/SDC of 2D seismic interval velocity grids

Perform multi-2D merge of Average velocity between PSDM and PSTM area

Perform Spatial Data Conditioning (SDC) on 2D seismic velocity grids (extracted from the velocity cube) in order to produce an optimized 2D seismic velocity grid, to be input to the depth conversion in Step 2.

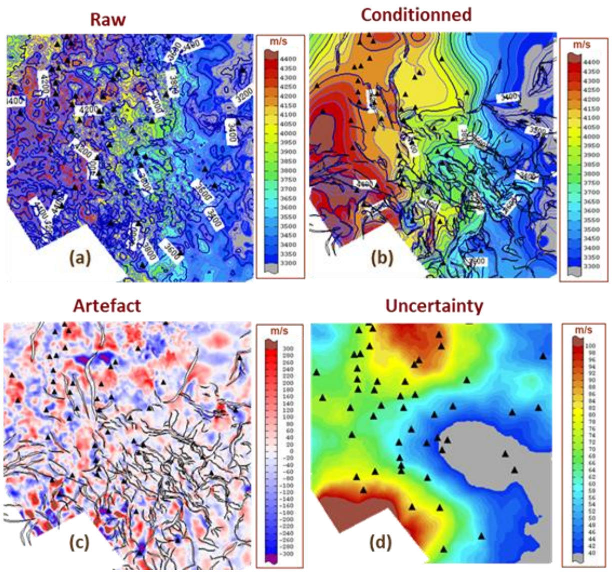

Figure 10– Spatial conditioning of seismic layer velocities (artefact removal) optimizing the calibration to the wells

Step 2: Multi Layer Velocity model building and depth conversion of key horizons

Bayesian cokriging algorithm optimizes the computation of the rescaling factors to be applied to each of the seismic velocity maps for all layers.

This optimized set of rescaling factors minimizes the depth residuals for all the converted horizons at all the available well marker location simultaneously

As a result, uncertainty on input time interpretations and seismic velocity fields is translated into reliable mathematical confidence intervals (kriging standard deviation) around optimized rescaling factors and best estimated depth maps.

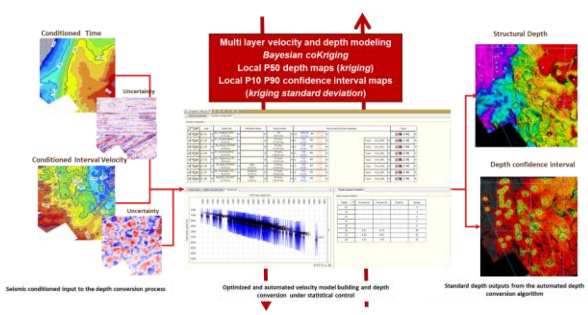

Figure 11– Optimization of the parameters of the depth conversion using Bayesian co kriging

Step 3 : Computing Closure probability maps with spill points locations and GRV expectations curves

The quantification of the confidence interval attached to a depth conversion scenario enables (conditional simulations or ensemble based algorithms) to derive alternative depth maps representing "structural" P10 P50 and P90 depth cases from which prospects may be targeted.

P10 minimum case with 90% chance for its GRV to be exceeded in reality, P50 medium case with 50% chance , P90 maximum case with only 10 % chance for its GRV to be exceeded in reality

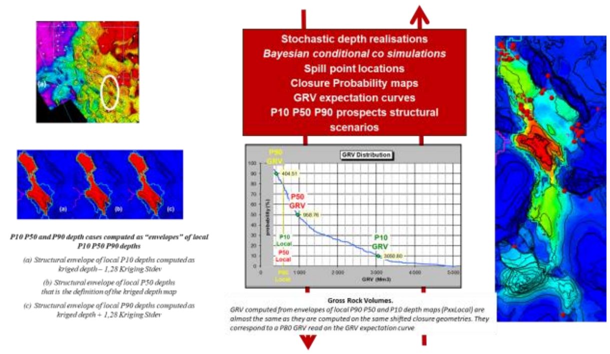

Figure 12– Automated outputs of the EI workflow including closure probability maps and GRV expectations curve for each identified prospect.

Conclusions

O&G geological reservoirs are a valuable Earth Resource.

The optimal valuation of O&G reservoirs is key to make them an economical and sustainable solution to the problem of energy supply.

At the digital age, Earth Intelligence machine learning algorithms allow for building "smart reservoir digital twins" that best support decision making when designing and operating E&P projects

Earth Intelligence:

- unifies deterministic building of alternative SCENARIOS as one single consistent P10 P50 P90 stochastic scenario
- consistently optimizes and automates geophysical modelling workflows and thus consistently integrates geophysical data in the E&P decision making processes
- opens the way for replacing "black box" 3D earth numerical models by "Probabilistic Scenarios" producing smart reservoir digital twins that geoscientists will share, discuss and update with confidence when supporting more efficient making on E&P assets.

Acknowlegments

To Seisquare company for the development of the UDOMORE EI software platform and performance of the North Sea case study

References

1_SBGF 2009 Depth conversion and associated uncertainties using consistent velocity model:A probabilistic unified model based on Bayesian approach
Luc Sandjivy, Arben Shtuka, SeisQuare, France

2/ SBGF 2011 Local Stationary Modeling for Reservoir Characterization
Shtuka Arben, Piriac Florent and Sandjivy Luc (SEISQUARE, France)

3/ EAGE 2018 Building a stochastic geophysical workflow for consistent prospect targeting: a North Sea Case Study
Mickael Collet (Seisquare), Luc Sandjivy (Seisquare), Robert Pfau (ConocoPhillips Norway)*

4/ EAGE DIGITAL 2021 :KRIGING SEASON 3 From GEO_SCIENCES to GEO_DATA_SCIENCES
Luc SANDJIVY , SEISQUARE

5/ EAGE DIGITAL 2022 : Earth Intelligence® for Digital Earth Resource Management
Luc SANDJIVY Earth Resource Management Services

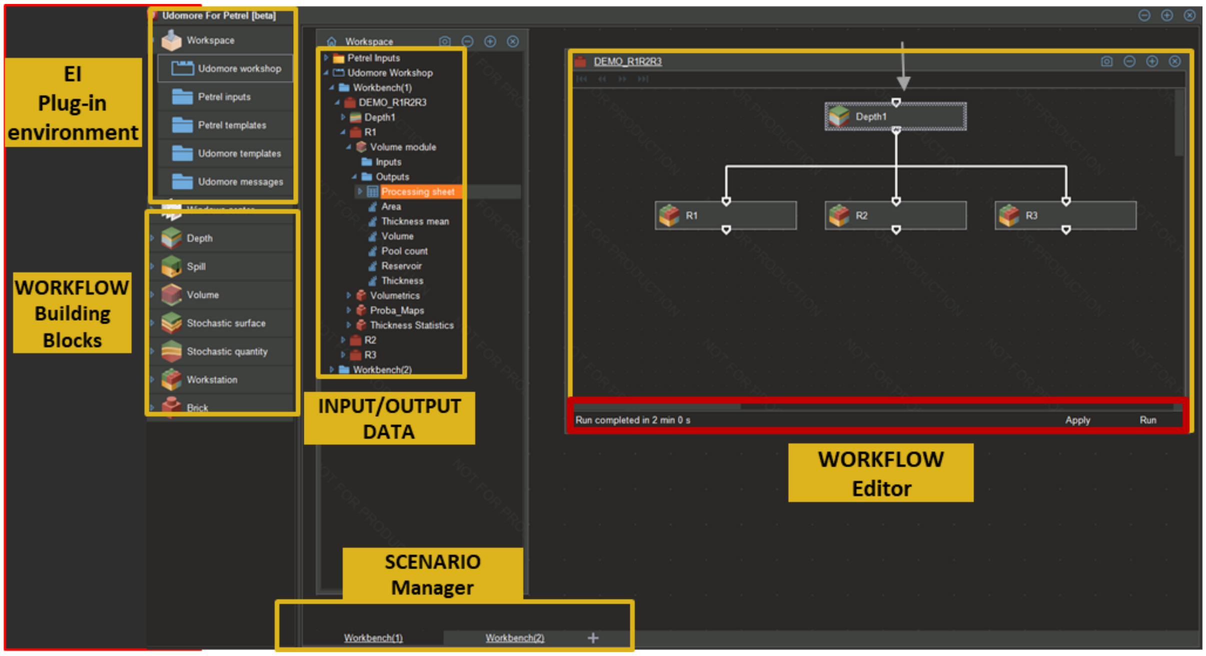

Figure 5 : The UDOMORE EI Platform interface (courtesy of Seisquare Company)

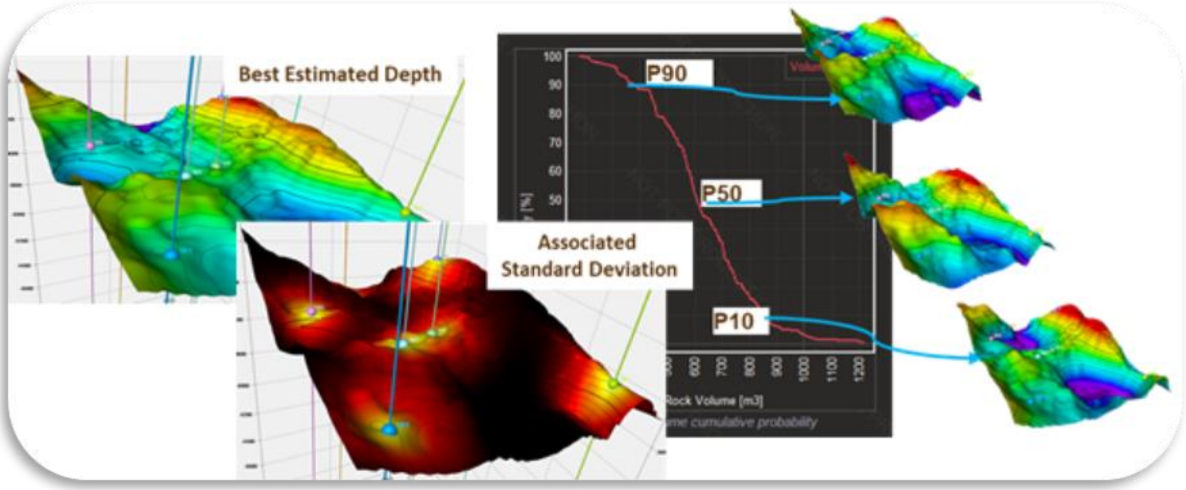

Figure 6: Digital geomodels twins generated in real time