Conditioning a surface-based model to log data: application to the Karoo data set

Antoine Bertoncello, Hongmei Li and Jef Caers
Introduction

- Surface-based models recreate realistic subsurface structures and heterogeneities
- **BUT** the conditioning is arduous:

  *Requirement on data*
  *Costly inverse modeling*

/model created by surface based model
*(Bertoncello and Caers, 2010)*
Motivations

- A conditioning methodology have been developed and tested on a model with few parameters are influent.

- We want to test the conditioning methodology when a sensitivity analysis does not lead to a simplification of the model.

East-Breaks data set (Bertoncello and Caers 2010)
Surface-based model: recall

Geologic concept is integrated into reservoir models using rules and statistics *(from process-based models or other analysis)*
Surface-based model: recall

Net-to-Gross

1% 70%
Possible lobe locations for a same set of parameters

Both inputs parameters and geobodies location can be optimized to match desired data (wells, seismic...)
# Parameters to optimize

<table>
<thead>
<tr>
<th>Lobe geometry</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Length</td>
</tr>
<tr>
<td></td>
<td>Thickness</td>
</tr>
<tr>
<td></td>
<td>Variance/Covariance of the</td>
</tr>
<tr>
<td></td>
<td>thickness variation</td>
</tr>
<tr>
<td>Lobe location</td>
<td>X Y of the lobe in the domain</td>
</tr>
<tr>
<td>(spatial uncertainty)</td>
<td></td>
</tr>
<tr>
<td>Geological process</td>
<td>Progradation intensity</td>
</tr>
<tr>
<td></td>
<td>Migration intensity</td>
</tr>
<tr>
<td></td>
<td>Influence of topography on</td>
</tr>
<tr>
<td></td>
<td>deposition</td>
</tr>
<tr>
<td></td>
<td>Type of erosion process</td>
</tr>
<tr>
<td></td>
<td>Frequency of intermediate</td>
</tr>
<tr>
<td></td>
<td>shale</td>
</tr>
<tr>
<td>Initial condition</td>
<td>Coordinates X Y of the</td>
</tr>
<tr>
<td></td>
<td>sediments source</td>
</tr>
</tbody>
</table>
Parameters to optimize

\[ N_{\text{parameters}} = N_{\text{general\_parameters}} + N_{\text{lobes}} \times N_{\text{lobe\_parameters}} \]

10 lobes $\Rightarrow$ 7 + 8*10 = 87 parameters

A simplification of the problem is required
Methodology

- Identify the leading uncertainty
  Spatial or parameter?
- Sensitivity analysis on parameters
- Reformulation of the optimization problem

Not necessary leads to a simplification of the problem
Methodology

General parameters

- Progradation intensity
- Migration intensity
- Erosion type
- Location source X & Y

Initial Topography

Lobe

Lobe 1
- Width
- Length
- Thickness
- Variance/Covariance
- X Y coordinates

Lobe 2
- Width
- Length
- Thickness
- Variance/Covariance
- X Y coordinates

Lobe 3
- Width
- Length
- Thickness
- Variance/Covariance
- X Y coordinates
Methodology

Optimization

General parameters

- Progradation intensity
- Migration intensity
- Erosion type
- Location source X & Y

Step 1

predefined

Depositional surface

Lobe 1
- Width
- Length
- Thickness
- Variance/Covariance
- X Y coordinates

Lobe 2
- Width
- Length
- Thickness
- Variance/Covariance
- X Y coordinates

Lobe 3
- Width
- Length
- Thickness
- Variance/Covariance
- X Y coordinates
Methodology

Step 2

Optimized

General parameters
- Progradation intensity
- Migration intensity
- Erosion type
- Location source X & Y

Optimization

Lobe 1
- Width
- Length
- Thickness
- Variance/Covariance
- X Y coordinates

Lobe 2
- Width
- Length
- Thickness
- Variance/Covariance
- X Y coordinates

Lobe 3
- Width
- Length
- Thickness
- Variance/Covariance
- X Y coordinates

Depositional surface
Lobe

predefined
Optimization reformulation

Step 3

Optimization

Optimized

Lobe 1

- Width
- Length
- Thickness
- Variance/Covariance
- X Y coordinates

Lobe 2

- Width
- Length
- Thickness
- Variance/Covariance
- X Y coordinates

Lobe 3

predefined

General parameters

- Progradation intensity
- Migration intensity
- Erosion type
- Location source X & Y
Optimization reformulation

Step 4

Optimized

General parameters
- Progradation intensity
- Migration intensity
- Erosion type
- Location source X & Y

Depositional surface

- Width
- Length
- Thickness
- Variance/Covariance
- X, Y coordinates

Optimized Lobe 1

Optimized Lobe 2

Optimized Lobe 3

Optimization

- Width
- Length
- Thickness
- Variance/Covariance
- X, Y coordinates
For each step

Initial population → **GA** → Best individual → **NM** → Optimized solution

**GA** Genetic Algorithm

- Efficient for global search
- Not based on gradient
- Use a set of individual solutions modified after each iteration

**NM** Nelder-Mead (polytope)

- Efficient for local search
- More sensitive to gradient
- Work on one single solutions (not a full population)
Application to the Karoo data set
Application to the Karoo data set

9 wells data

Source 1

Source 2

Deep water EOD
## Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th># Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 sources locations</td>
<td>4</td>
</tr>
<tr>
<td>Flow direction</td>
<td>2</td>
</tr>
<tr>
<td>Number of lobes</td>
<td>2</td>
</tr>
<tr>
<td>Depositional model</td>
<td>3</td>
</tr>
<tr>
<td>Location of the lobes</td>
<td>2</td>
</tr>
<tr>
<td>Average thickness</td>
<td>1</td>
</tr>
<tr>
<td>Average width</td>
<td>1</td>
</tr>
<tr>
<td>Average length</td>
<td>1</td>
</tr>
<tr>
<td>Noise</td>
<td>3</td>
</tr>
</tbody>
</table>

10 lobes \( 8 \times 10 + 11 = 91 \) parameters
What is the leading uncertainty?

- Parameters uncertainty
- Spatial uncertainty
- Output variability

Possible lobe locations for a same set of parameters

σ = 2.63

σ = 2.57

No leading uncertainty
Define the most influencing inputs parameters

-> interaction between parameters to consider
-> Interference with spatial uncertainty

No leading uncertainty

10 lobes \( 8 \times 10 + 11 = \)
91 parameters
- 11 parameters for step 1 (general parameters)

- 8 parameters for the following steps (lobe specific parameters)

\[
8 \times 10 + 11 = 91 \text{ parameters}
\]

- 500 iterations per step: 400 for GA and 100 NM

\[
10 \text{ lobes} = 5500 \text{ iterations} \sim 3 \text{ hours}
\]
Results after optimization
Results after optimization
Results after optimization

![Graph showing Measured Net-to-Gross vs. Simulated mismatch with data points and trend line. The graph includes a scale for Net-to-gross with negative and positive values.]
Define 5 ensembles of 100 realizations

Each ensemble fit more or less the 8 wells

For each realization, the mismatch with the 9th well is computed (predictability)
Define 5 ensembles of 100 realizations

Each ensemble fit more or less the 8 wells

For each realization, the mismatch with the 9\textsuperscript{th} well is computed (\textit{predictability})
Predictability of the model

Define 5 ensembles of 100 realizations

Each ensemble fit more or less the 8 wells

For each realization, the mismatch with the 9th well is computed (predictability)
Predictability of the model

Quality of the Match
Conclusion

- The method match thickness and facies at data location
- The conditioning approach is iterative
- This approach is in two steps
  - Optimization environmental input parameters
  - Optimization the lobes features
- Further work are required to study the predictability of the model