A method for locally adaptive gridding and local updates of the geological structure in earth models

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Motivation

- Interpretation of complex geological structure is uncertain and has large impact on decision making for geosteering, field development, drilling operation, ...
- While drilling: should take full advantage of all available measurements
- Effective handling of complex structural uncertainties require new methods
  - Local updates while drilling based on new measurements at sub-seismic scale
  - Uncertainty modelling: structure, fluid flow, volume estimation

Current methods (e.g. Petrel and RMS)

- A global grid property represents both structure and properties
  - Ineffective to regenerate the complete grid each time the structure is modified
  - Effective structural updates can only be achieved by manipulation of the existing grid
- Today’s automatic methods for local updates of the structure are limited to:
  - Geometric perturbation of the base case structural model [4], e.g. slightly adjust location and displacement of existing faults [1], adjust thickness and depth of layering [2]
  - Geometric perturbation cannot handle (or very limited):
    - Local updates of the structural topology (how faults are connected, depositional structure and stratigraphy, insert new faults/layers, etc.)
    - Unforeseen geological events, or to update the geological concept used in the interpretation (e.g. “is local scale compression taken up by faulting or folding?”)
- Once decided, the resolution of grid and structure cannot be effectively updated
- Result (in particular for complex structural uncertainties)
  - Only part of the uncertainty is captured in the model – Uncertainty is underestimated
  - Sub-optimal support for geosteering (structure is not properly updated while drilling)
  - Poorly estimated uncertainties in structure, fluid flow, reservoir volume

Suggested method for local updates of structure and grid

- Structure and properties are modelled separately (Fig. 1)
  - Properties not in a single grid, but in multiple property functions
  - The structure splits the subsurface into regions that are independently handled
  - Each region is separately discretized at the required scale ➔ set of subgrids
- A subgrid and a property function is linked via a geometric mapping f
  - The mapping allows population of subgrid from property function
- Automatic operators based on geological parameters locally update the structure
  - Insertion/removal/update of faults and layers, erosion, folding and other geological events in a geologically realistic manner
- Advantages
  - Structural modelling and local updates not constrained by grid
  - Local updates: if the structure is locally modified, only subgrids in the immediate neighbourhood must be updated. The rest of the subgrids are kept
  - Grid resolution can be locally modified, e.g. fine scale around and ahead of the drill bit
  - Automatic updates enable uncertainty handling of the structure
  - Geological concept used for interpretation can be locally modified (“faulting or folding?”)
  - Local scale uncertainty handling, multiple geological concepts within local part of model
  - Individual management of each region and subgrid enables parallel processing
- Almost everything modelling (e.g. while drilling)
  - Model is never fixed and always updated with the most recent measurements
  - Always optimal grid resolution for the current purpose
  - Grid always available for various simulations during drilling (and seismic interpretation?)

Proof of concept & Future work

- Subsurface is split into regions that are separately handled (Fig. 1+2+3)
- Local updates
  - Structural topology: automatic operators locally insert new layers and faults (Fig. 2+3)
  - Grid resolution adapted to region of interest and facies type (Fig. 3)
  - Local scale uncertainty management of faulting in the interior of a fault block (Fig. 3)
- Method is prototyped in 2D, extension to 3D is conceptually straightforward
- Management of more complex structure, automatic operators based on geological parameters to handle geologic events, multi-scale modelling
- Uncertainty in well trajectory while drilling
- Adaptation of grid resolution to e.g. wave fronts in flow
- Model updates while drilling based on multiple measurements (deep EM, LWD logs)
- Local scale uncertainty handling of complex geology

Examples of complex structural uncertainties

- Fault network around a salt dome, salt tectonics
- Subseismic faults and layering, fault zone deformation, fault reactivation, size of a trap, conjugate faulting etc.

Figure 1: Mapping of properties into structure. Each region R in the structure is separately gridded and populated with properties from a property function Φ via the mapping f

Figure 2: Local update of layering: insertion of the new layer in yellow. The bottom layer in green is not changed

Figure 3: Automatic local updates of faulting and grid resolution in the interior of two fault blocks. Uncertainty modelling of the number of and displacement of faults in the interior of a fault block. Sands in orange at finer resolution than surrounding shales. Fault blocks of interest at finer resolution than other fault blocks.

References:
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