Introduction

Modelling of different geological concepts or comparing the effect of different interpretations is not often carried out as the capability, time and effort needed to do so using conventional modelling tools are not available. Sketch-based interface and modelling (SBIM; Olson et al, 2009) can overcome these constraints by replacing long, complicated workflows by intuitive sketches to build 3D models. Rapid Reservoir Modelling (RRM; Jackson et al, 2015) is an implementation of SBIM for subsurface modelling, that allows the user to sketch concepts or to trace interpretations over existing data in order to produce 3D reservoir models in a very short timeframe (minutes). These reservoir models can then be interrogated for a series of static parameters, and a built-in flow diagnostics module (Zhang et al., 2017) provides a first estimate of dynamic behaviour. The user can quickly generate a suite of models representing different scenarios or interpretations and compare or rank them using multiple derived parameters.

RRM can be used to quickly test what the effect could be of different interpretations or modelling decisions, before a reservoir modelling approach is finalised, or specific detailed models are built. It may help to decide on modelling parameters such as grid size, but also inform the inputs for uncertainty workflows (Pataki et al., 2019), as uncertainty associated with different concepts can be translated into RRM model outputs.

Here we will illustrate how sketches of different geological interpretations of the same dataset are used to construct 3D models using RRM, and show the impact these have on resulting model properties.

Method

SBIM creates 3D shapes from 2D drawings. Converting 2D sketches into 3D geological models requires information on:

- What the 3D surface geometry resembles based on one or more sketched lines that are drawn on one or multiple planes.
- How truncations between sketched lines are implemented to represent a geologically correct model.

Sketching is carried out on 2D planes that bound or intersect the model area (Figure 1). Sketches on multiple planes are combined and interpolated to generate a 3D surface. As sketches are added or modified, the resulting 3D geometry of a surface(s) is updated to give a continuous, on-the-fly visual feedback and QC of the model. Vertical planes are used for cross-section sketches, and horizontal planes for map view sketches or contouring. Cross-section sketches can be combined with a map view trajectory to produce an extruded 3D shape. Additionally, surfaces can be interpolated between multiple cross-section sketches or multiple map view sketches (e.g. contouring).

Appropriate truncation of sketches and surfaces is essential to capture the correct spatial relationships between different geological features (Rood et al., 2018). Two sets of operators allow all required flexibility to incorporate geological relationships and ensure models represent what is intended, not only in the sketched plane, but also in 3D.

- The first set of operators defines how new sketches and surfaces modify previously existing surfaces (e.g. eroding previous sketches).
- The second set of operators allow the use of existing surfaces as boundaries between which to add new, successive sketches.

Both types of operators can be combined to allow the flexibility to sketch a model in any order (bottom to top, top to bottom, large to small) as different datatypes or different might have a different intuitive order of interpretation.
**Figure 1** Screenshot of the RRM interface. Three main windows provide the views necessary to sketch a model, clockwise from top: Cross section sketching window, Map view sketching window, 3D visualisation window. The cross-section window has data loaded from five measured outcrop sections and wells. The position and orientation of the cross section is visualised in transparent pink in the 3D visualisation window. The map view sketching window has a map loaded as a background image showing the well locations and the cross section. The leftmost panel will list all sketched surfaces and volumes (in stratigraphic order) and associated properties.

**Well correlation example (Book Cliffs, Utah)**

A series of wells can often be correlated in a variety of ways, which may depend on the data available, the depositional concept applied, and geological expertise or experience of the user. Figure 2 shows a 3D reservoir model based on one possible correlation between five measured outcrop sections and wells (Figure 1; top) from the marginal-marine and shallow-marine strata of the Spring Canyon Member in the Book Cliffs (Utah), using data from Kamola and Von Wagoner (1995) and Campion et al. (2010). These data and associated outcrops are widely used in training subsurface professionals and students to develop geological interpretation skills, but the value of outcrop training can be significantly enhanced by translating the correlation panel between measured outcrop sections and wells into 3D reservoir models that demonstrate the impact of different geological interpretations.

Sketching one iteration of such a model from blank screen takes less than 5 minutes. Making small modifications is significantly faster, as individual sketches can be modified or undone and replaced by a different sketch. This could include a complete new surface geometry with a new interpretation, or simply altering a trajectory (e.g. of a parasequences or channel).
Figure 2 Sketched 3D reservoir model based on five measured outcrop sections and wells. The parasequence boundaries (flooding surfaces) and facies boundaries are correlated by sketching in the cross-section window (top) displaying the measured outcrop sections and well logs in background (Figure 1). These sketches are extruded along the trajectories sketched in map view (bottom right). Parasequences 1 to 3 (from top to bottom) are extruded using the green, brown and yellow trajectories respectively. Flood tidal deltas (red in middle PS) follows the same trajectory. Tidal channel (red in upper PS) follows the red trajectory on the map view.

Uncertainty exists in how different interpreted sequence stratigraphic surfaces, facies belts and geobodies are correlated between the wells, and also in the map view geometry of the surfaces, belts and geobodies. Because it is fast to created multiple different models, the impact of such interpretation-based uncertainty can be tested quickly. Output of RRM models include volumetrics for different facies (Figure 3), exported gridded surfaces, and flow diagnostics (e.g. effective permeability, time-of-flight) are available directly so they can be used to quantitatively compare models.

Figure 3 Facies proportions in parasequences 1-3 (from top to bottom) of the sketched model in Figure 2. These proportions are based on the 3D model, not just on the cross section, and thus also takes into account the map view interpretation of the parasequences.
Conclusions

SBIM is a new approach to subsurface modelling. Integration of sketching with geological operators and flow diagnostics positions RRM as a fast, geologically intuitive prototyping tool for reservoir modelling. Assessing the sensitivity and uncertainty of different concepts or interpretations allows users to make informed decisions about subsequent modelling efforts or about which modelling approach or workflow to use. Furthermore, it is a valuable approach for training in geological interpretation skills, in front of an outcrop or directly on subsurface data.

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References


