Facies Modelling of a Real-Life Fluvial System Using a Modern Object-Based Algorithm

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Summary

When choosing which approach to take when doing facies modelling there has traditionally been a trade-off between geological realism and how much well data to incorporate into your model. If geological realism had the priority, the choices available typically are stochastic object-based modelling techniques. With an abundance of well data the choices have been pixel based algorithms, such as Indicator or Multi-Point Statistics, since object modelling has taken too long time to be able to correctly condition to the well data.

Recently, we published a new object modelling algorithm that has significantly increased the well conditioning capability compared to previous methods. Here, we demonstrate this solution applied to a fluvial reservoir with meandering channels in the North Sea, where we obtain perfect well data conditioning for all four modelled facies, channel, levee, crevasse and background. The geological geometries that are needed to represent each of the facies are honoured, while still allowing for enough flexibility to condition to well data and maintaining their geological realistic shapes.

With a significantly faster algorithm, the new facies object modelling solution again becomes relevant in any setting involving automatic generation of many realizations.
Introduction

Fluvial depositional environments are present in many reservoirs around the world, and have therefore received considerable attention in the petroleum industry. Moreover, as fluvial reservoirs may be highly heterogeneous and challenging to model, they have received considerable academic attention with many publications on this topic (e.g. Keogh et al. (2007), and references therein). One of the early breakthroughs in the technology was to represent fluvial channel deposits as objects, which allowed the stochastic models to honour geologically realistic geometries, which in turn greatly improved the predictive power in the reservoir flow communication (e.g. Georgsen et al. 1994).

Drilling technology has had a steady progress since object modelling techniques were introduced. We are now faced with both more complicated well geometries and densely spaced wells, potentially providing a large set of well data which needs to be honoured in the model. We have previously demonstrated that the new channel object modelling algorithm is capable of conditioning to hundreds of densely spaced wells (Hauge et al. 2017), proving that modern object models can cope with the present-day reality of having abundant well data (Figure 1). In this study we investigate how a next generation object-based algorithm handles data from a real reservoir case of a fluvial channel system, including crevasse and levee facies associations. The presented object model is based on the model described in Holden et al. (1998), and has also large similarities to Deutsch & Wang (1996).

Figure 1 This example from a synthetic case with over 300 densely spaced wells demonstrates the effectiveness of the new algorithm to condition on many observations of an object, while avoiding areas with background observations (i.e. other facies types).

Background

We use open source data from the Gullfaks field, located in the North Sea, on the western flank of the Viking Graben. The main reservoir of the Gullfaks field is the Brent group of Middle Jurassic age. The upper formations Tarbert to Ness are deposited in a fluvial deltaic environment (Pettersson et al. 1990). The deltaic system was prograding towards north, with subsequent retrogradation (Halland et al. 2014).

In this study we focus on the fluvial deposits of the Ness formation. Ness is interpreted as a delta plain associated with coals, mudstones and siltstones, and with channel deposits containing fine to medium grained sandstones. The depositional style is also suggesting a high degree of crevasse deposits (Pettersson et al. 1990). We have created a modelling grid selecting three subzones of the Ness formation; upper, middle and lower Ness.

We have interpreted facies data for 7 representative wells in the area, which includes deviated wells, and wells crossing faults. The well data are a mix of channel, crevasse and levee observations, and
makes this study area ideal to demonstrate the linking of associated facies objects in the new algorithm.

**Object model description**

Corresponding to the geological setting, our object model has three object types: Channels, levees and crevasses. These are connected, with levees flanking the channels, and crevasses breaking out through the levee from the channel, as shown in Figure 2. The mathematical model is described in (Hauge et al. 2017). This publication also describes the channel parameterisation and well conditioning algorithm in more detail. We parameterise channels along a centre line, with horizontal edges described by 1D Gaussian fields, and top and base described by Gaussian 2D fields with a channel shape as expectation. These Gaussian fields serve the double function of providing stochastic variability, and enabling well conditioning in dense well patterns.

The levee parameterisation is very similar to the channel parameterisation. As levees are always connected to a channel, they follow the same centre line. Furthermore, one horizontal edge is given by the channel edge, whereas the other edge is defined by a 1D Gaussian field describing the levee width. The top and base are 2D Gaussian fields, with a trend describing the levee shape. The levee connects to the channel edge as shown in Figure 2.

Crevasses are modelled slightly different. These are parameterised around a backbone, consisting of two connected straight-line segments, one describing the breakout direction from the channel, and one describing the flow direction for the crevasse after the breakout. The horizontal shape is given by a trend for left and right edge, and 1D Gaussian fields are added to these. Furthermore, the top and base is given by 2D Gaussian fields with trends, just as for the channel and levee. The leftmost channel in Figure 2 illustrates how the crevasses (green) are breaking through the levees out from the channel margins.

![Figure 2](image_url)

*Figure 2* One realisation with crevasse and levee facies coupled to the channel deposits.

**Modelling results**

In *Figure 3*, we show the well match for a conditional realisation. This match is exact for all wells used in this study. The realisation is shown in *Figure 4*, which also shows the well pattern. Running
time for this realisation was 1.5 minutes on a standard PC. As the figure shows, the new algorithm makes proposals in accordance with geological specifications as well as honouring well data fast. In Figure 5 we show in more detail how the conditioning of objects looks in an intersection view along the more complex wells. Note how the objects are picking up their respective positive conditioning points, while carefully avoiding the observations of other facies types.

**Figure 3** Well conditioning for the 7 wells used in this study, where the original well log is displayed to the left and the results from facies modelling to the right. There is no mismatch in any of the wells. Note that the blank spaces in the original well log are due to blocking of horizontal and deviated wells, displayed against MD.

**Figure 4** A realisation for the three Ness zones in the Gullfaks field. Channel, levees and crevasses are all linked together with an erosional hierarchy, which leads to geologically realistic facies deposits consistent with well data.
Figure 5 These figures are examples of how the new algorithm also handles complex situations, such as wells crossing faults as well as horizontal wells. The figures show intersections with the well with logs (pale colours) and the grid. On the left figure, the well data should be compared to cells on the left of the trajectory, and on the right figure, logs should be compared to the cells above the trajectory.

Conclusions

We have shown that our modern object-based algorithm can generate geologically realistic realisations, with coupling of levee and crevasse objects to their associated channel objects, while also correctly condition to well data. The new algorithm is smarter at making proposals consistent with the well data, and therefore efficiently achieves exact well conditioning even in complex situations, such as with deviated wells. This opens a new era for object-based facies modelling in multi-realization and ensemble based settings, where speed is essential, and also where correct well conditioning is required to avoid manual, non-reproducible changes which would have broken the automated and repeatable workflow designed to explore realistic geological scenarios for the reservoir under study.

References


