Conditioning Event-based Channelized Facies Models (Alluvsim) to Multiple Well Data

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This paper introduces an alternative approach in conditioning event-based fluvial models. The geological complexity generated by event-based (also known as process-based or pseudo-genetic or advanced object based models) is appealing to many geologists. The complexity is believed to have a significant affect on fluid flow and recovery predictions. Event-based models are difficult to construct such that well and seismic data are reproduced. One approach to use the structure of such models is to use them as training images for multiple point statistics based algorithms. Those algorithms have their own challenges; it would be useful to create event-based facies model reproducing one to five wells. The `alluvsim` *program was adapted to reproduce channel fill and non-channel intersections from multiple wells together with areal and vertical trend information that comes from seismic and well data. The results of this new approach are promising; however, challenges remain in presence of many well data or the requirement to reproduce non-channel facies such as levees and crevasse splays.*

Introduction

The *alluvsim* algorithm was developed for constructing realistic channelized models in fluvial or deepwater settings (Pyrcz, 2004). The basic approach is to simulate discrete geological events using a streamline or evolving channel centerline as the basic building block. The technique was originally called streamsim or streamline simulation; however, it was renamed as event-based modeling to avoid confusion with streamline-based flow simulation. Event based geologic models lead to realistic channel morphologies and flow events including avulsion, aggradation, and meander migration. It also provides a high flexibility in reproducing a variety of reservoir types and fluvial styles.

The original formulation for *alluvsim* was as an unconditional simulation algorithm algorithm to simulate fluvial depositional systems. The timing and placement of depositional events was controlled, with a stochastic component, to honor available soft data including areal and vertical trends. This algorithm was then extended to update prior constructed streamlines for well conditioning. This led to a different program named *alluvsimcond*. The rules that enforced conditioning in the first version of *alluvsimcond* worked very well with very few wells. The motivation of the current research is to extend the rules in alluvsimcond to reproduce at least five wells, which is common in early field development when important reservoir modeling decisions are being made.

The idea was also to refine the code with additional testing and deliver a single stable program to CCG sponsors.

Unconditional and conditional simulation is possible with the updated alluvsim program. The goal to permit reproduction of up to 5 wells has been met. In fact, conditioning to many more wells would be possible in a favorable case, that is, a case where the spacing of the wells is fairly large relative to the scale of the channelized objects. The approach for conditioning was significantly revised. The resulting methodology is described below with some examples using different wells and channel geometries.

Methodology

Each channelized feature and associated facies will be considered as a depositional event. The channel streamline or centerline evolves over some period of time to mimic lateral accretion and the creation of associated facies. The evolution of the centerline is based on the well established bank retreat model. Additional facies are associated to each event as appropriate. The events are constructed according to a schedule that is setup to approximately reproduce areal and vertical trends. The events are then updated to reproduce net facies intervals (channel fill elements without differentiation of CH (channel), LA (lateral accretion), LV (levees), CS (crevasse splays) and FF(CH) (abandoned channel) elements). The events are also modified to ensure that net facies are not placed where wells have intersected non-net facies.

The current implementation is designed to reproduce the net facies intervals at each aggradation level while maintaining the sequence of flow events to mimic the depositional process. Rather than drawing and placing streamlines to just honor the soft data and updating them later to match the well data, the new methodology applies acceptance/rejection rules to select the best candidate streamlines that match the well intersections before they are placed according to the event schedule. The details of this implementation are described below

The key idea is to select the geologic events that have a high potential to reproduce the available conditioning data. The details:

1. Candidate streamlines are generated according to the number specified by the used and with user-specified channel properties such as azimuth, sinuosity, and source location. They are also weighted by areal trend. These generated streamlines with their properties are kept in streamline table.
2. For each aggradation level, starting from the bottom, the first streamline on a level is randomly drawn from the streamline table. It is selected according to the acceptance/rejection rules (for well conditioning case) before being placed on that level along with the attached architectural elements. These acceptance/rejection rules are applied mainly for screening the drawn streamlines to select the ones with the potential to match the conditioning data. These rules are described immediately below.

3. The drawn streamline is first checked for an unwarranted intercept. If the channel facies associated to an event (streamline) intersects a non-net interval in a well, it is discarded and a new streamline is drawn. This is repeated until some maximum number of tries has been reached.
4. The streamline (without any unwarranted intersections) from step 3 will then be checked if it intersects with any net intervals on this level. If the thickness of the net facies intersection is within a specified tolerance, then we keep the event for subsequent post processing. If the thickness is not matched well, then additional events will be tried. A maximum number of tries is specified. The best match is kept if the tolerance is not met.
5. Steps 2-4 are repeated for the new streamline associations until reaching net-to-gross (NTG) for this level.

These steps are repeated for all levels. Some post-processing is considered to fine tune the match with conditioning data for all intersections. Every net interval is checked. The closest net event is located and corrected to match the actual intersection. The horizontal location is corrected to attract the channel object to intersect and /or match the thickness of the well interval. This is done iteratively by shifting streamline horizontally until the thickness of the closest channel object is within the thickness tolerance. The vertical location is also corrected to match the top of the well interval. The entire streamline association is then shifted vertically to match the net elevation.

Some Results

The methodology described above was implemented to generate realizations with different events for various combinations of number of wells and net intervals. The input parameters and well data are shown in Table 1 and Table 2, respectively. The net to gross (NTG) value and percent well violation were calculated for each model constructed with a different value of random number seed, see Table 3. Figures 1 to 5 illustrate the realizations constructed for each case. There is a possibility to generate channel fill facies in violation of a well intersection if the maximum number of iterations is reached. These unwarranted intersections may be observed in the models constructed with a large number of wells and intervals (Figure 4 and 5). The effect of other input parameters on resulting streamline and facies models can be found in Alluvsim User's Guide (Zabel and Pyrcz, 2005).

1 well 2 intervals

Figure 1 shows overall streamline model and YZ and XZ cross sections of facies model constructed to honor the well data and the soft data for 0.2 NTG. The location of well number 2 is at X=500 m and Y=500 m.

2 wells 3 intervals

Figure 2 shows overall streamline model and YZ and XZ cross sections of facies model constructed to honor the well data and the soft data for 0.2 NTG. The location of well number 1 is at X=500 m and Y=200 m and that of well number 2 is at X=500 m and Y=500 m.

3 wells 4 intervals

Figure 3 shows overall streamline model and YZ and XZ cross sections of facies model constructed to honor the well data and the soft data for 0.2 NTG. The locations of well 1 and well 2 are the same as in Figure 2 and the location of well 3 is at X=500 m and Y=800 m.

4 wells 5 intervals

Figure 4 shows overall streamline model and YZ and XZ cross sections of facies model constructed to honor the well data and the soft data for 0.2 NTG. The locations of well 1-3 are the same as in Figure 3 and the location of well 4 is at X=200 m and Y=500 m.

5 wells 6 intervals

Figure 5 shows overall streamline model and YZ and XZ cross sections of facies model constructed to honor the well data and the soft data for 0.2 NTG. The locations of well 1-4 are the same as in Figure 4 and the location of well 5 is at X=875 m and Y=500 m.

Conclusions

An iterative methodology was developed to condition event-based facies models. This is only the start, but channel fill intersections in multiple wells are approximately reproduced. Post processing will still be required to completely match the channel fill intersections and to match associated net facies such as levees and crevasse splays. There is also a need to formulate the event-based methodology to other geological settings. This work will be extended in the future.

References

Pyrcz, M.J., *Integration of Geologic Information into Geostatistical Models,* Ph.D. Thesis, University of Alberta, Edmonton, 2004.

Deutsch, C.V. and Journel, A.G., *GSLIB: Geostatistical Software Library and User's Guide,* 2nd Edition, Oxford University Press, 1998.

Zabel, F. and Pyrcz, M.J., *Alluvsim User's Guide*, Version 1.0, Centre for Computational Geostatistics, University of Alberta, Edmonton, 2005.

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                            Parameters for ALLUVSIM
                            ***********************

START OF PARAMETERS:
welldata_1well2CH.dat               -file with well data
1 2 3 4 7 9                         - wcol,xcol,ycol,ztcol,zbcol,fcol
50.0 50.0 1.0                       -xanis,yanis,zanis
50.0 10.0                           - buffer, ztol
none                                -file with tbhe horizontal trend
1                                   - htcol
none                                -file with the vertical trend
1                                   - vtcol
100 100 100                         -ntime,max_assoc,max_withinassoc
3 7.0 13.0 17.0                     -nlevel,level elevations
0.2 50.0 20.0                       -NTGtarget,mdistMigrate,stdevdistMigrate
100 10 10                           -CHndraw,ndiscr,nCHcor
0.3 0.3                             -probAvulOutside,probAvulInside
90.0 1.0                            -CH element: mCHazi,stdevCHazi
500.0 -1.0                          -  mCHsource,stdevCHsource
4.0 0.5 0.2                         -  mCHdepth,stdevCHdepth,stdevCHdepth2
15.0 2.0                            -  mCHwdratio,stdevCHwdratio
1.3 0.2                             -  mCHsinu,stdevCHsinu
1.0 0.1                             - LV Element: mLVdepth,stdevLVdepth
80.0 5.0                            -  mLVwidth,stdevLVwidth
1.0 0.1                             -  mLVheight,stdevLVheight
0.0 0.0                             -  mLVasym,stdevLVasym
0.0 0.0                             -  mLVthin,stdevLVthin
0 0                                 -  CS Element: mCSnum,stdevCSnum
0 0                                 -  mCSnumlobe,stdevCSnumlobe
50.0 20.0                           -  mCSsource,stdevCSsource
200.0 50.0                          -  mCSLOLL,stdevCSLOLL
30.0 10.0                           -  mCSLOWW,stdevCSLOWW
100.0 20.0                          -  mCSLOl,stdevCSLOl
20.0 10.0                           -  mCSLOw,stdevCSLOw
0.03 0.05                           -  mCSLO_hwratio,stdevCSLO_hwratio
0.02 0.05                           -  mCSLO_dwratio,stdevCSLO_dwratio
0.0  0.0                            - FFCH Element: mFFCHprop,stdevFFCHprop
100 5.0 10.0                        -nx,xmn,xsiz
100 5.0 10.0                        -ny,ymn,ysiz
40 0.25 0.5                         -nz,zmn,zsiz
19512 .1                            -random number seed, color_incr
alluvsim.out                        -file for output facies file
streamline.out                      -file for output updated streamlines
fitness.out                         -file for measure of fitness with well data
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Table 1. Input parameters for Alluvsim

Well number	X coordinate (m)	Y coordinate (m)	Z top elevation (m)	Z bottom elevation (m)
1	500	200	13.1	10.0
2	500	500	17.0 7.1	15.1 4.3
3	500	800	13.1	10.0
4	200	500	7.1 13.1	4.3 10.0
5	875	500	7.1	4.3

Table 2: Well data

Case	Random Number Seed	Actual NTG	Percent Well Violation (%)
1 well 2 intervals	19512	0.45	6
2 wells 3 intervals	65808	0.45	15
3 wells 4 intervals	84684	0.45	16
4 wells 5 intervals	24436	0.45	29
5 wells 6 intervals	69769	0.47	35

Table 3: Actual NTG and percent well violation for the best model constructed for different combinations of number of wells and net intervals

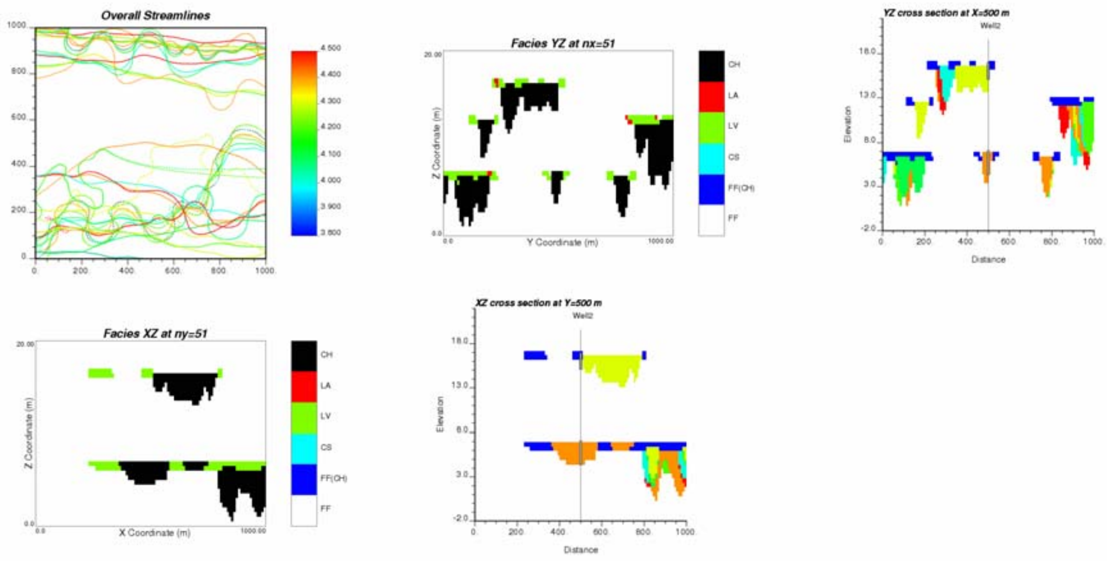

Figure 1: Overall streamline model and YZ and XZ cross sections of facies model for 1 well and 2 intervals.

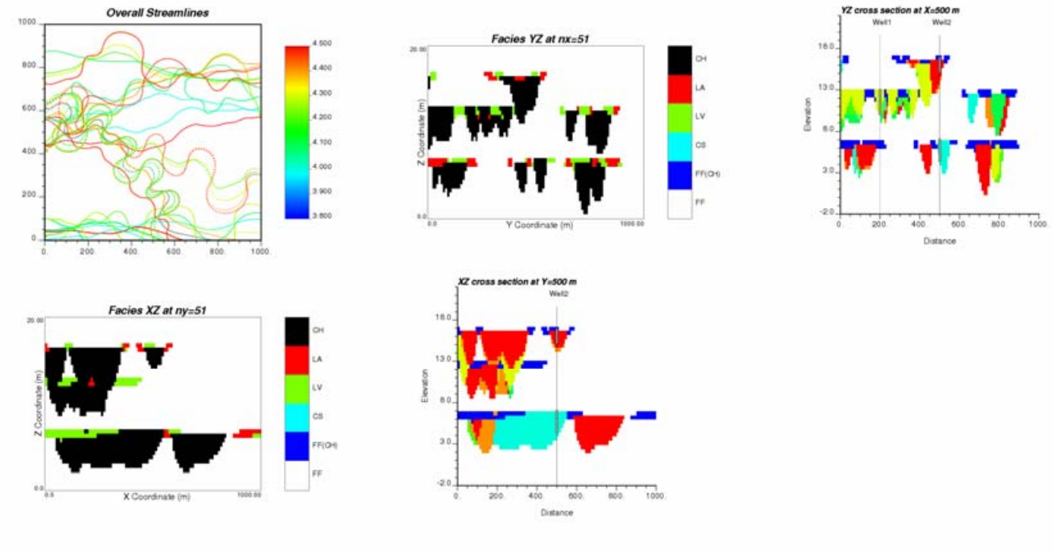

Figure 2: Overall streamline model and YZ and XZ cross sections of facies model for 2 wells and 3 intervals.

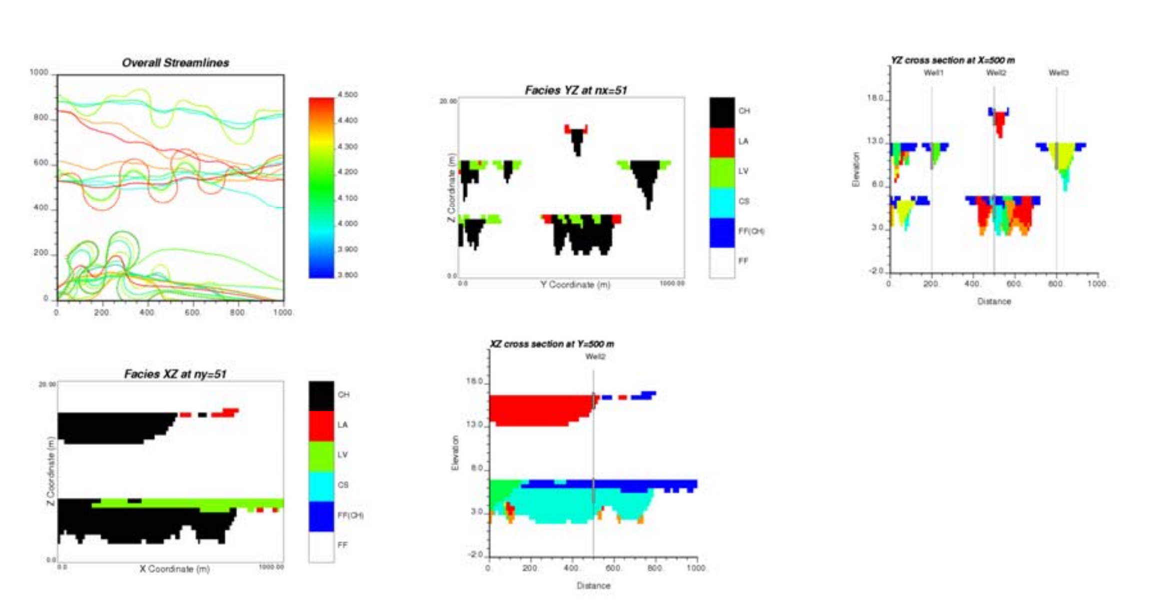

Figure 3: Overall streamline model and YZ and XZ cross sections of facies model for 3 wells and 4 intervals.

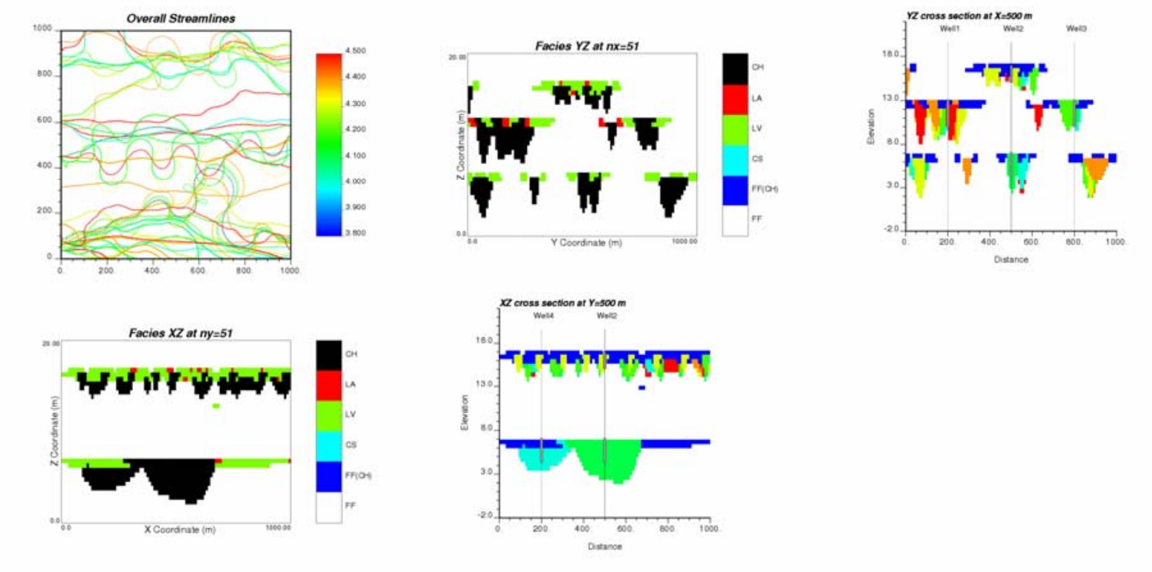

Figure 4: Overall streamline model and YZ and XZ cross sections of facies model for 4 wells and 5 intervals.

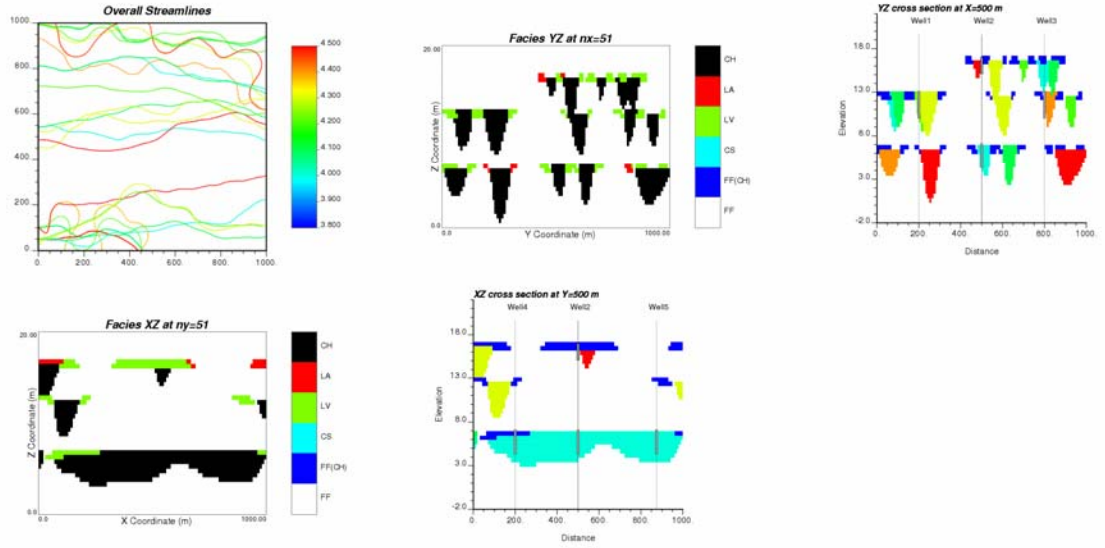

Figure 5: Overall streamline model and YZ and XZ cross sections of facies model for 5 wells and 6 intervals.