Post Processing Object Based Models to Reproduce Well Data: `MAPSpp`

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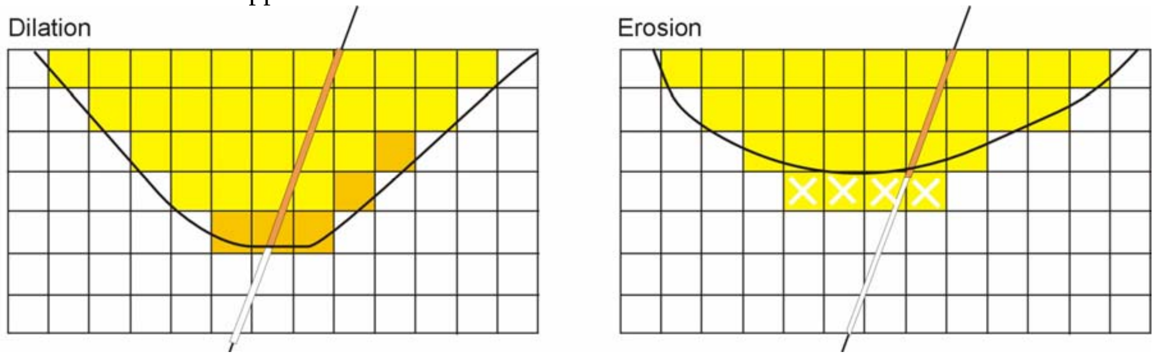
Stochastic simulation of facies is important before the assignment of porosity and permeability. Object based models are particularly suited to situations where the original sedimentary structures are preserved and have a large affect on fluid flow. Object based models reproduce well data with varying degrees of success, with more difficulty in situations with large numbers of wells. There is a need to post process object based models that do not exactly reproduce all of the available small scale well data. The facies intersections at well locations must be reproduced without unrealistic short scale variations away from the well locations. A post processing algorithm is implemented to accomplish this post processing.

Introduction

Object based models look realistic and have of large scale curvilinear features that are not easily created by other techniques. A longstanding problem with object-based models is the reproduction of dense well control. Sophisticated rule-based algorithms and iterative schemes reduce this problem, but do not completely eliminate the possibility of slight mismatches at well locations. There is a need for a flexible post processing algorithm to enforce well data reproduction without introducing artifacts.

The goal is a realistic approach to erosion/dilation to account for the following situations: dilation on the left and erosion on the right. It may be unrealistic to embed the actual channel-like geometry in the algorithm as shown by the schematic black line; however, we would like the final cell-based model to appear realistic.

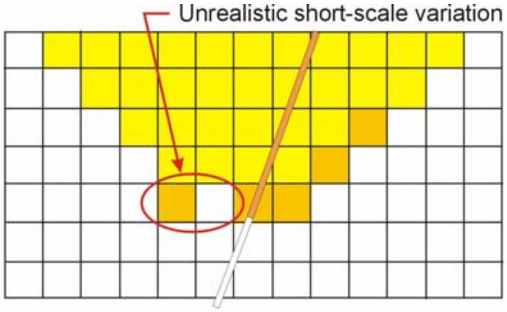


The methodology developed in this note works with the cells and their statistical relationship with surrounding cells; there is no explicit manipulation of object geometries. A cell-based statistical procedure has the advantage of (1) simple post processing and (2) easily extended to multiple facies such as levees and crevasse splays.

Methodology

An image analysis technique is applied in post-processing mode to enforce well conditioning data with smooth changes. The realization should only be changed near wells where the observed intersections do not match the image to be post processed. Cells that are candidates for a change in facies are identified as those within an ellipsoidal range from cell-well values that mismatch. The cells at the mismatched locations will be visited first and a spiral search will be used until the ellipsoidal range is reached.

The algorithm will be applied sequentially; a change is considered at a grid location by considering the well mismatch and all previous grid node changes. The original MAPS algorithm was not sequential; however, the goal here is for the erosion/dilation to be smooth away from the wells and not have unrealistic short scale variations. The sketch below shows a situation we want to avoid. If the cell on the right is unchanged, then the cell on the left should also be left unchanged; the algorithm has to be sequential so that changes are smoothly propagated away from the wells with a mismatch.



The probability of changing the facies assignment at a grid cell location will be established by two factors: (1) the facies in nearby grid cells and (2) the new facies that is being assigned at the cell intersected by the well (to correct a mismatch). The affect of the mismatch will decrease as the cell under consideration gets further from the well.

The probability of each facies prevailing at any particular cell location **u** is calculated based on a weighting function:

$$p(\mathbf{u},k)=\frac{1}{S}\sum_{\mathbf{u}'\in W(\mathbf{u})} w(u')\cdot i(\mathbf{u};k), \quad k=1,\ldots,K$$

Where *S* is a standardization constant, *W(***u***)* is a template of weights centered at the location under consideration and *i(***u***;k)* is the indicator of facies *k* at location **u**. There is much discussion on the weighting template in the original MAPS paper. A reasonably small template (5x5x5) appears to work well. A larger template induces excessive smoothness and a smaller template does not enforce smooth enough transitions away from the well locations.

All cells under consideration in the sequential path are within a reasonably close distance to a cell-well mismatch. There is some probability that the cell under consideration should also be changed to the observed facies at the well. This probability should be one at the well location and decrease as the distance from the well increases. The distance of the cell to the well is standardized by the ellipsoidal radius, then the probability to observe the same facies as the well is increased by the following factor:

$$f = (1 - d)^{\omega}$$

Where f is the increased probability of the same facies as the well, d is the standardized distance between 0 and 1, where d=0 at the well location and d=1 at the maximum distance from the well. The ω factor controls how quickly this factor decreases with distance; a value of ω=2 was found reasonable. So, f is added to the $p(\mathbf{u};k)$ value corresponding to the facies k at the well.

The only other factor change is to slightly modify f by a random number, that is, multiply by a random number between 0.9 and 1.1. This avoids an excessively blocky behavior if the mismatch is in a homogeneous region of another facies. The algorithm runs extremely fast and wells are honored smoothly with few visual artifacts.

Program

The `MAPSpp` program follows standard GSLIB conventions. Most of the functions are available in GSLIB. The parameters for the program:

```
Line
 1    Fluvsim/fluvsim01.dat       -file with well conditioning data
 2    2  3  4  5                  -  columns for X, Y, Z, facies
 3    -1.0      1.0e21            -  trimming limits
 4    Fluvsim/fluvsim01t.out      -file with inital image
 5    1                           -  column for categorical variable
 6    MAPSpp.out                  -file for simulation output
 7    1                           -number of realizations
 8    100 25.0  50.0              -nx,xmn,xsiz
 9    100 25.0  50.0              -ny,ymn,ysiz
10    100 0.005  0.01             -nz,zmn,zsiz
11    69069                       -random number seed      |  These should be frozen and
12    9  9  2                     -max distance to update  |  not made user adjustable
13    2.0                         -weighting exponent      |
14    2  2  2                     -MAPS window (cells)     |
```

The conditioning data are specified on **Lines 1-3** The input OBM is specified on **Lines 4-5.** The output file is specified is on **Line 6.** The number of realizations on **Line 7.** The standard GSLIB grid definition is specified on **Lines 8-10.** The options on **Lines 11-14** will rarely need to be changes. These parameters are robust. The random number seed (**Line 11**) is to avoid undue blockiness in regions of constant facies types. Only cells within the maximum distance to update are considered (**Line 12**). The weighting exponent is as described above (**Line 13**). The MAPS window provides weights for the a-posterior probabilities (**Line 14**).

An Example

Nine well data were extracted from an unconditional `fluvsim` realization. These data were used to partially condition subsequent conditional `fluvsim` realizations. The simulated annealing parameters were set to stop quickly; the `MAPSpp` program will achieve the final conditioning. Figure 1 shows cross sections through the nine wells before post processing. Figure 2 shows the results after post processing. There are no significant visual artifacts.

Conclusions

To a large extent, OBM has been driven by a desire to reproduce large-scale depositional features. A criticism leveled against OBM is that it cannot reproduce extensive well control, which is true for many implementations of OBM. This has been a significant motivator for the development of multiple point statistics (MPS) based algorithms. Post processing the OBM models is a legitimate alternative.

It is very easy to reproduce 90 to 95% of the well data with object-based models such as `fluvsim`. This is true even when the well data are very closely spaced. The partially-conditioned object-based models are post-processed with a modified image-cleaning algorithm to ensure reasonable variations near the wells. The results share many features with the initial object-based models *and* they reproduce all of the well data.

References

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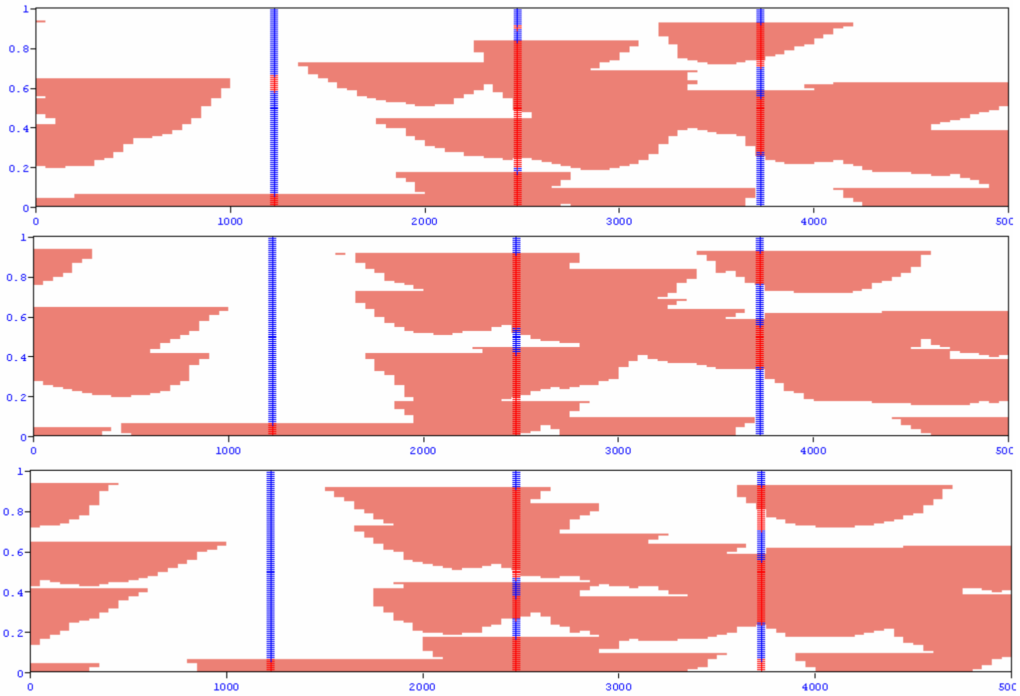

Figure 1: Reproduction of conditioning data before post processing.

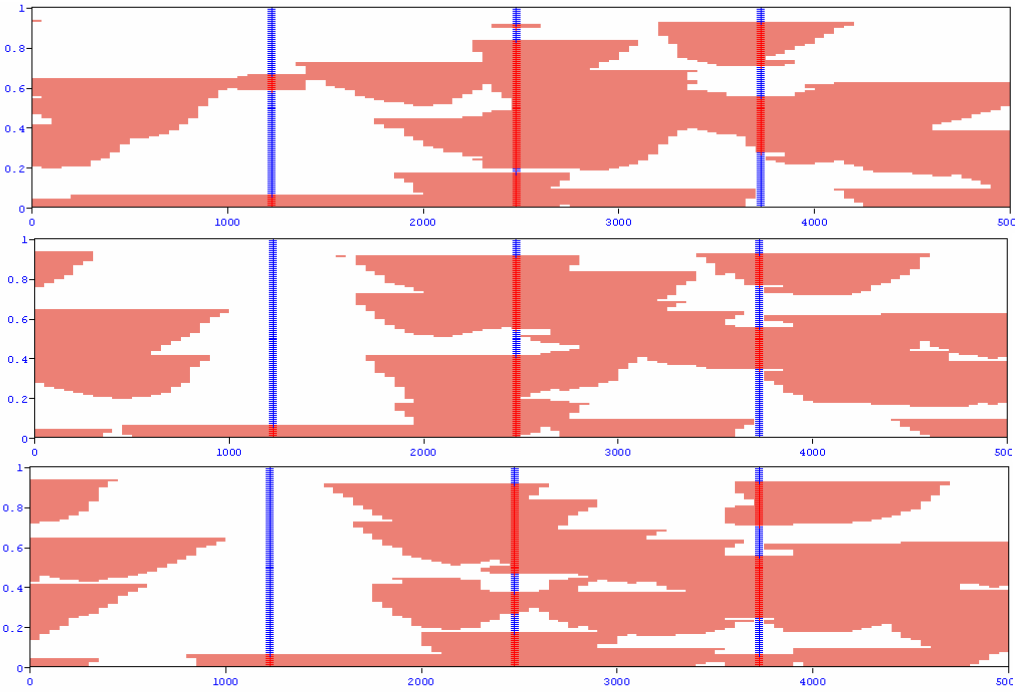

Figure 2: Reproduction of conditioning data after post-processing. Note that the well data are reproduced exactly.