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Marked point processes for modelling geometrical objects

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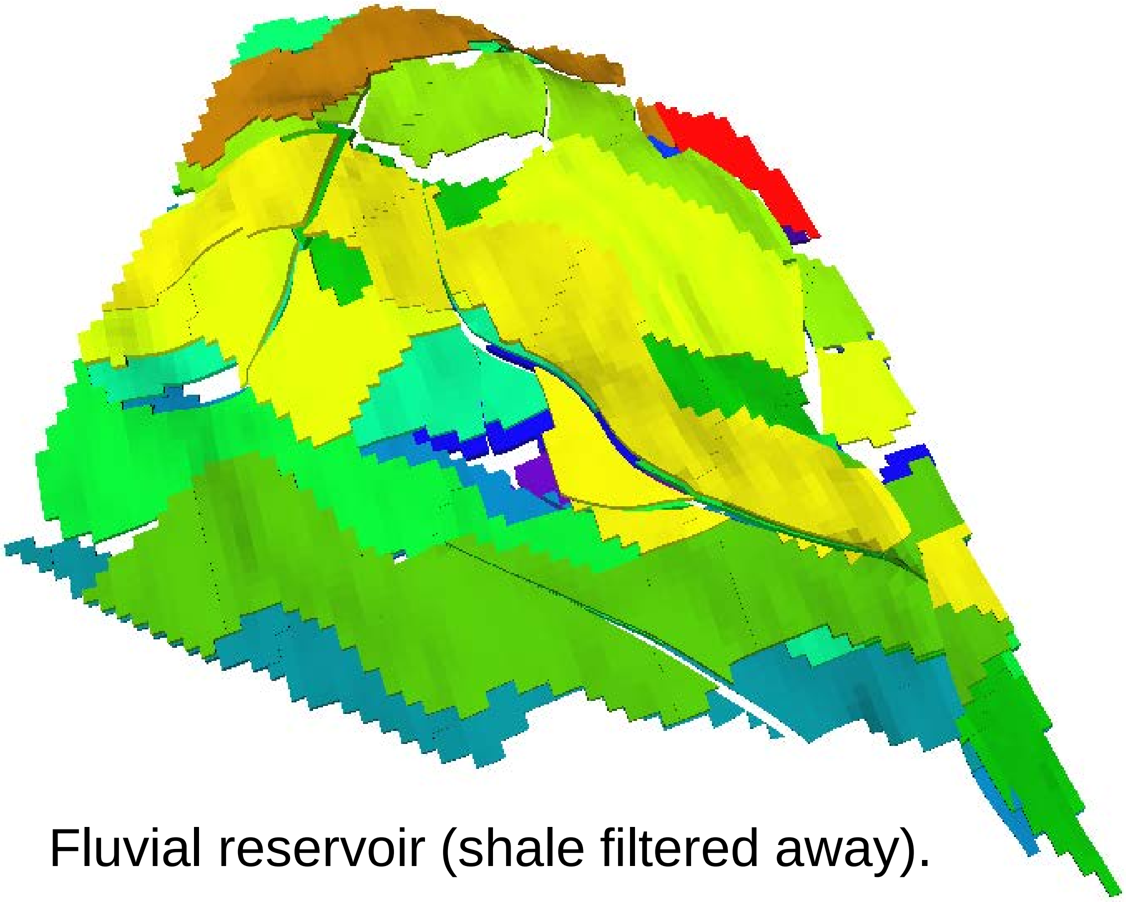
Idea: Describe geometrical facies objects located in a background

- Assumes we can describe the geometry of all facies except one.
- The final facies is used as background.
- Used in depositional environments.

Marked point process example: A fluvial reservoir



Fluvial reservoir (shale filtered away).

Sand channels (objects) located on a shale background.

Have a statistical model for the shape and distribution of channels.

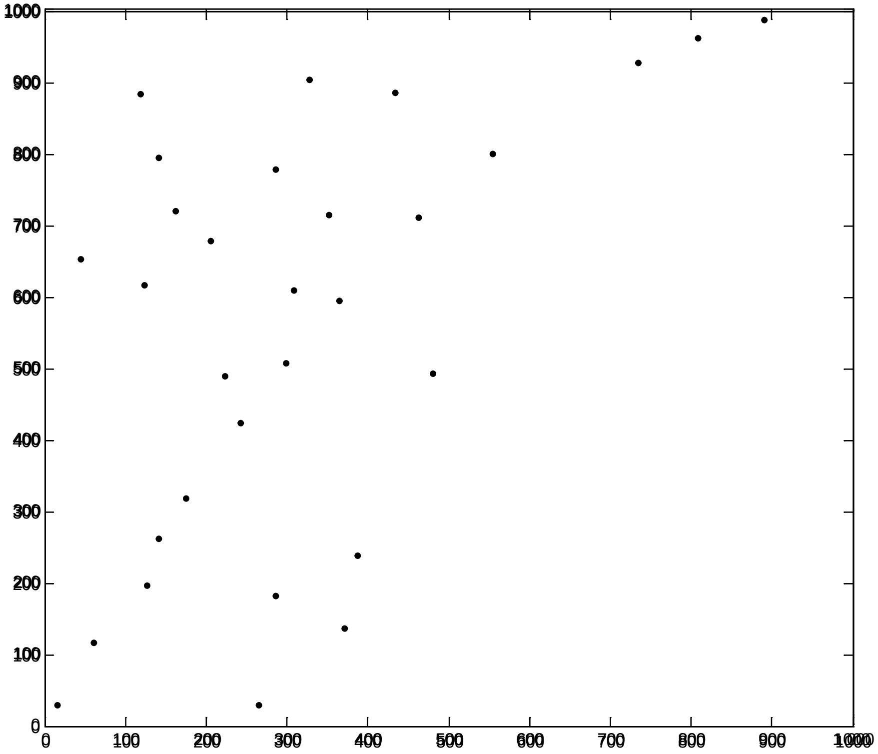
Statistical foundation: Marked point process

A point process gives the location of points in space.

For each location, there is a probability for a point.

Points can interact, typically repulsion.

Each point can have a set of marks, in this case a circle radius.



Object models were traditionally developed for fluvial reservoirs

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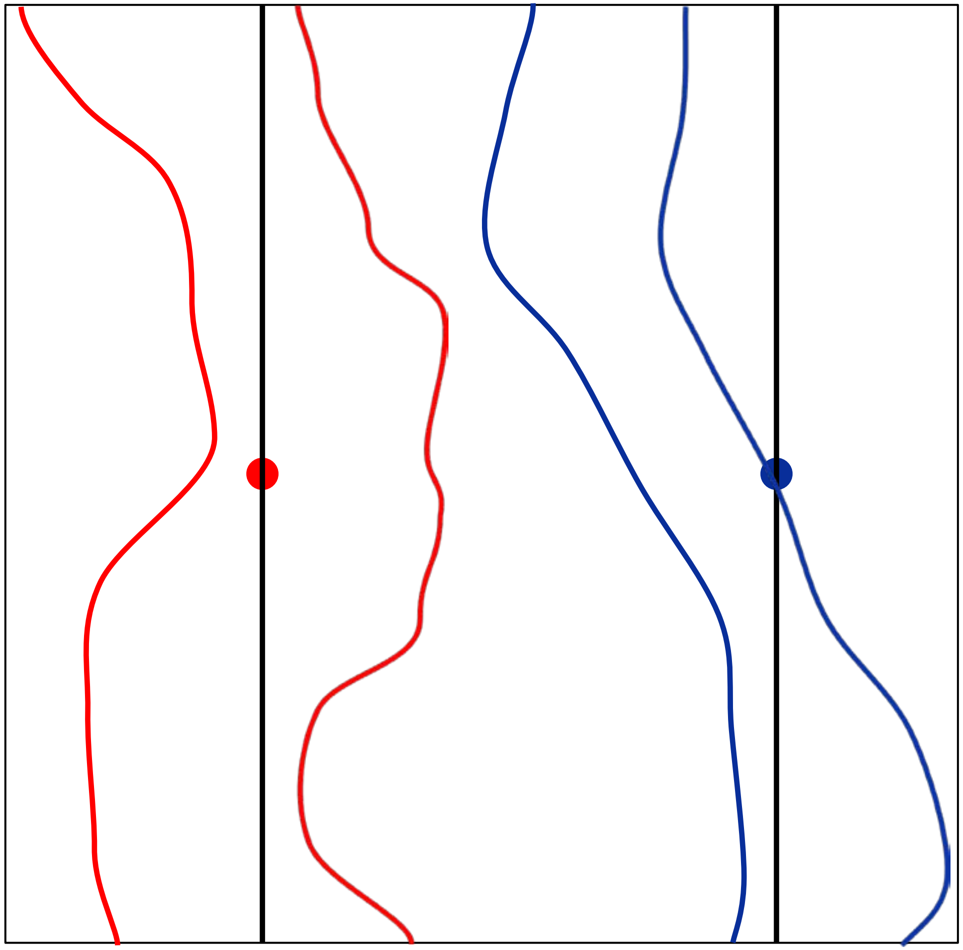
Volume fraction controls the number of channels.

The points are locations the channels pass through.

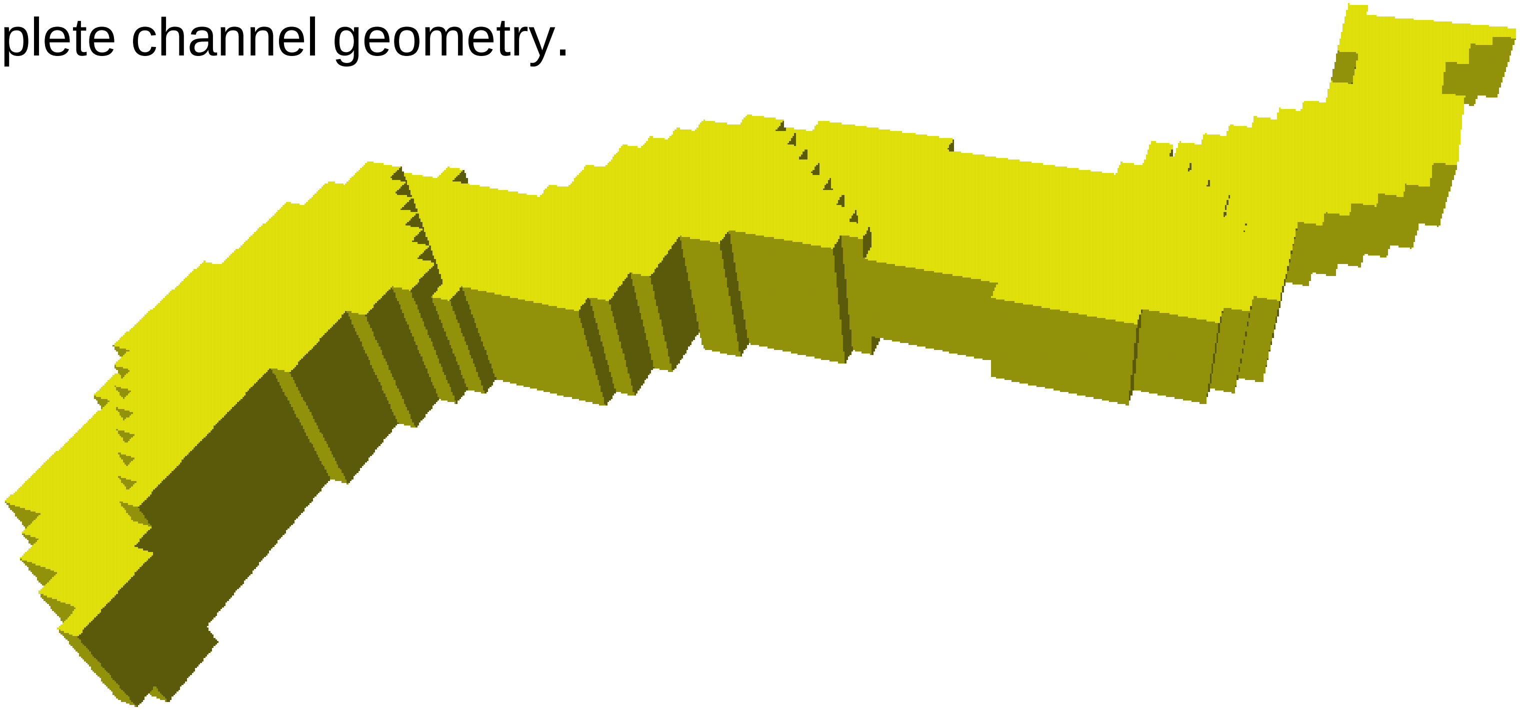
Marks:

- ► Direction of channel line.
- ► Mean width of channel.
- ► Local width of channel (1D Gaussian field).
- ► Local centre of channel (1D Gaussian field)



The vertical direction also has 1D fields for thickness and centre

Together, this defines a complete channel geometry.

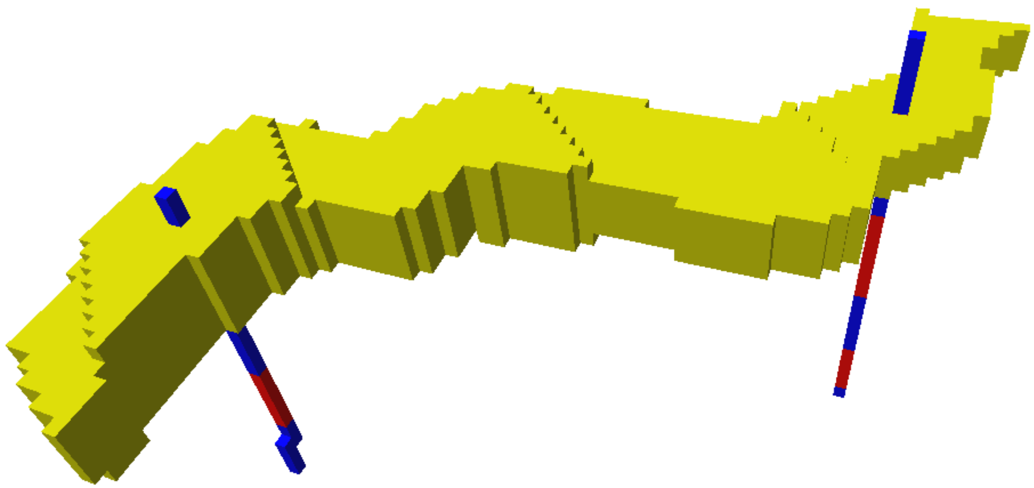


Well conditioning means placing objects to match wells

Basically simple:
Draw point and marks conditional on obs.

But should the channel condition more wells?

With more than one well, we do not know the true distribution for a channel.



Well
= Sand
= Shale

We must use an iterative algorithm to generate realisations

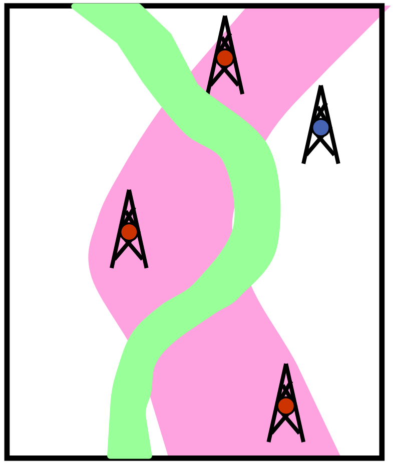
Given two realisations, we can find how probable they are relative to each other.

Can also do this with partial realisation.

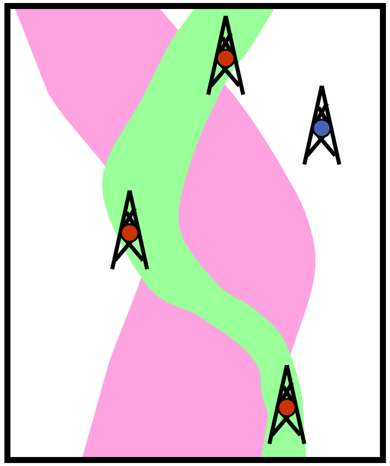
Algorithm:

1. Add or remove an object from the current realisation.
2. Check the relative probabilities, and accept or reject the modification.
3. Repeat until everything is ok.

This is known as Markov chain Monte Carlo



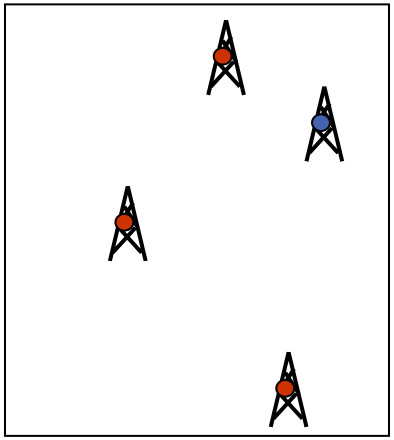
p = 0.999



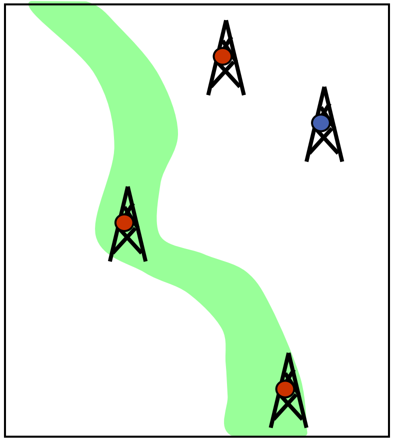
p = 0.001

Quick example of algorithm

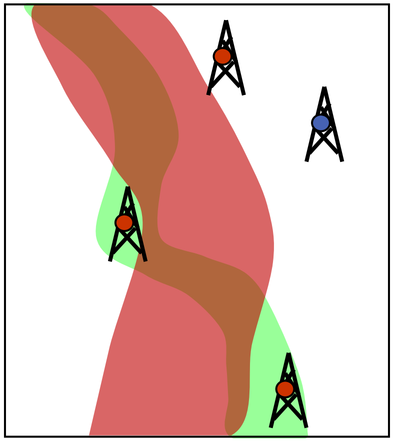
1) 4 wells, 3 with sand



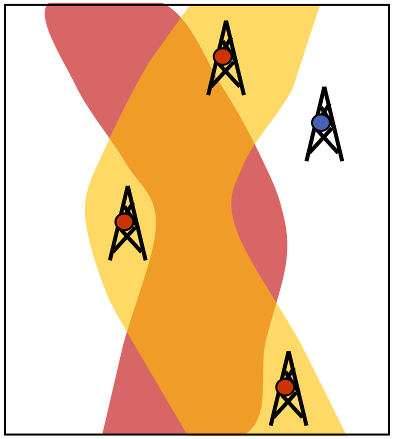
2) A small channel added



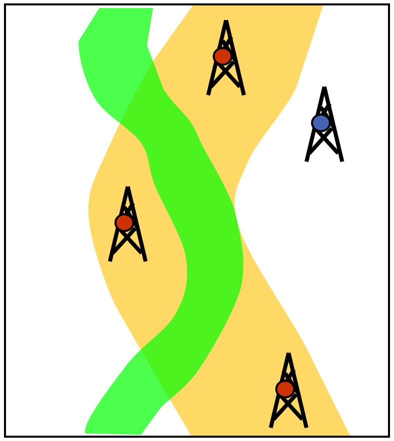
3) A wide channel is added



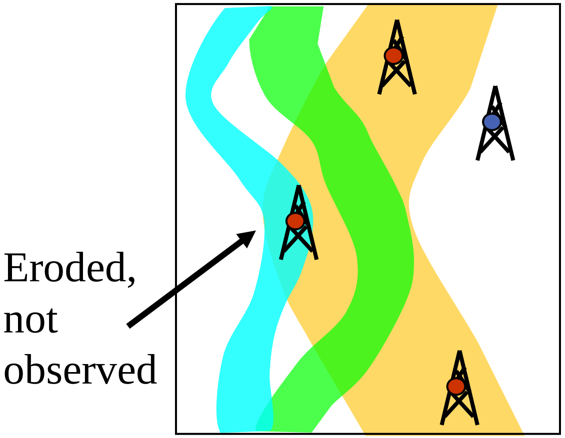
4) A new wide channel replaces the small



5) Unobserved wide channel replaced by a smaller



6) New channel added until sand/gross is met

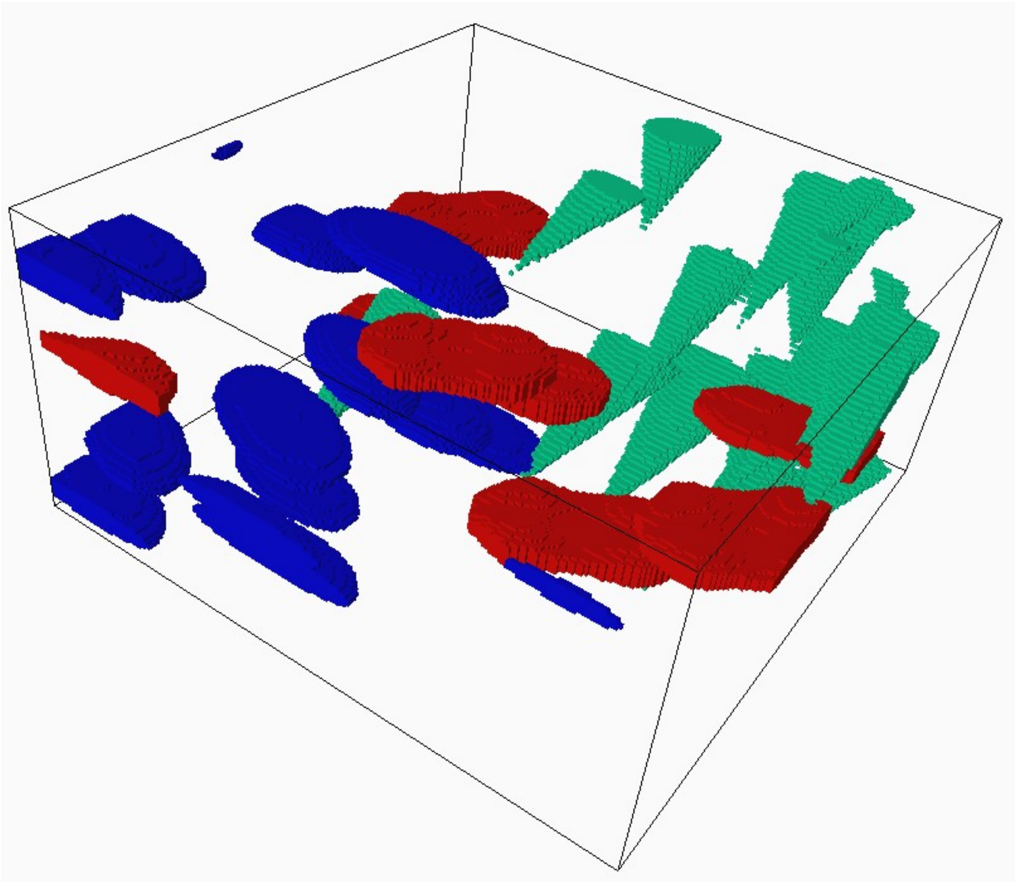


Objects can also have other shapes than channels

All we need is a way to describe the geometry.

Must also be able to describe variation:

- Global size (length, width, thickness).
- Local variation (thickness, width).



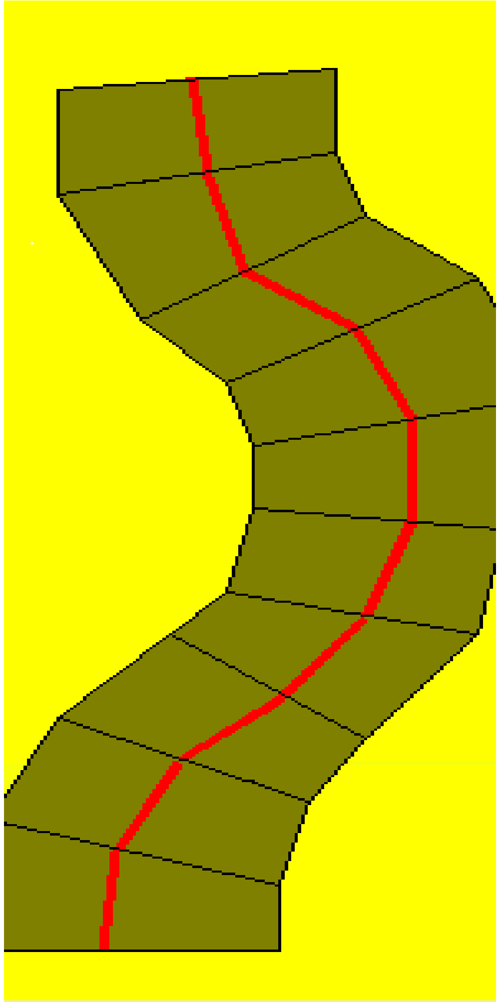
Parameterisation around a depositional line most common

Use a piecewise linear curve.

Defines depositional direction.

Can define trends along the line.

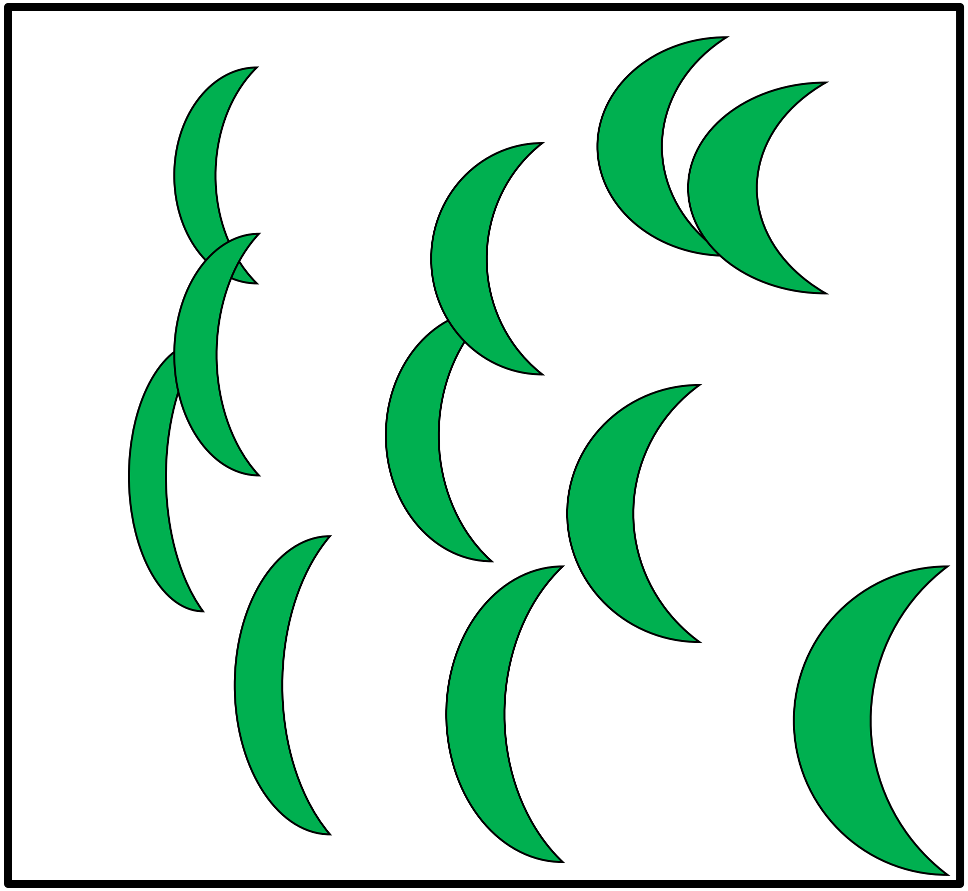
Can condition line to vector fields.



We can also include trends in the marks

Global size trends depend on location in grid.

Local shape trends depend on location along object.



Seismic data can be used for conditioning

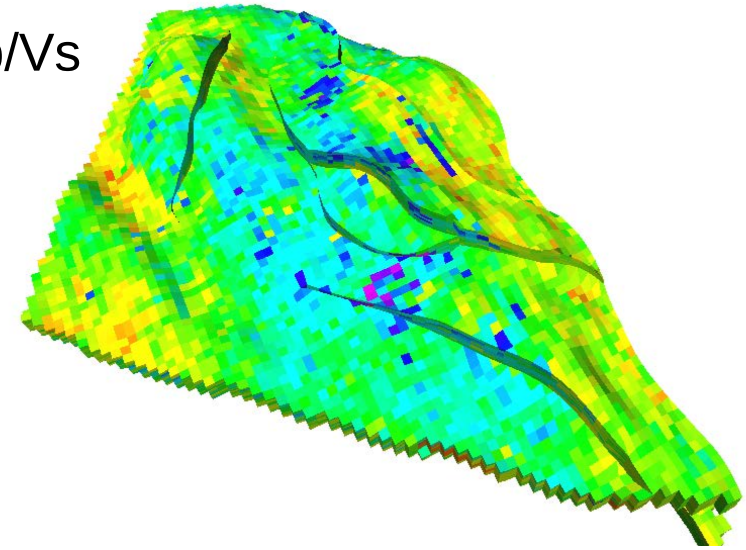
Input needed:

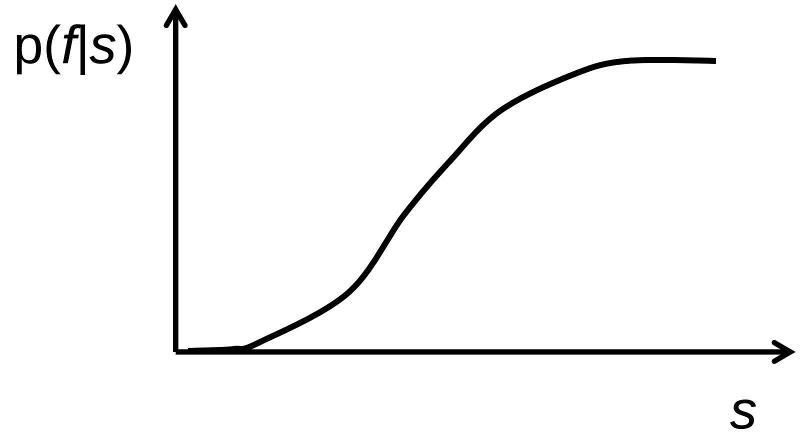
- Inverted parameter *s*.
- Probability function for facies *f*, p(*f*|*s*).

Can then compute for realisation *r*

$$p(s|r) = \prod_{i=1}^{n} p(f_i|s_i)^{k/n}$$

where *n* is #cells, *k* a tuning parameter.





The full model tries to balance many terms

$$p(r|s,w) = p_g(r)p_I(r)p(s|r)p_w(r,w)I_w(r,w)I_V(r)$$

Geometry

Interaction

Seismic conditioning

Well correlations

Well observations

Volume fractions

If these are in conflict, the algorithm may not converge.

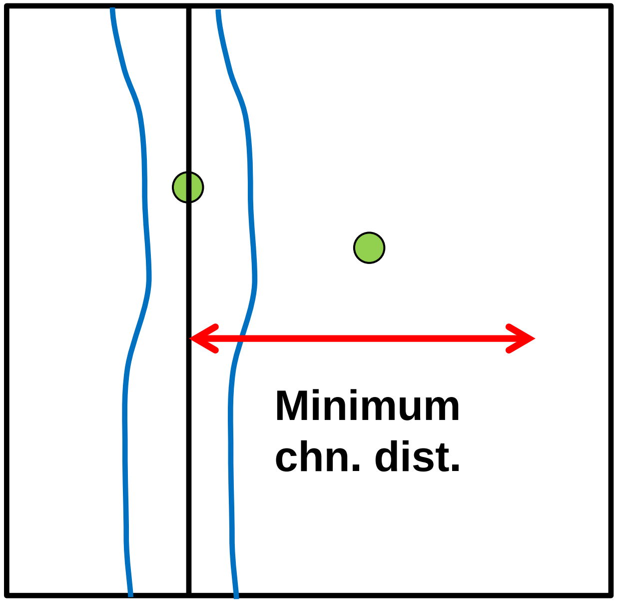
Object models may have convergence problems

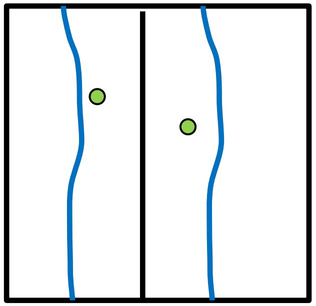
Example problem:
Interaction distance is larger than well distance.

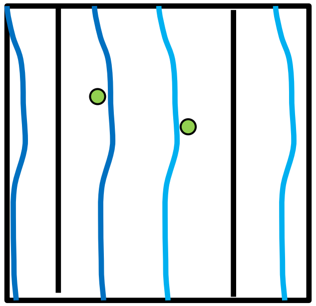
Possible solutions:
A. One wide channel.
B. Two wide channels.

If these are unlikely in prior, we may not find them.

May fail to condition wells, or achieve volume fraction.



A


B


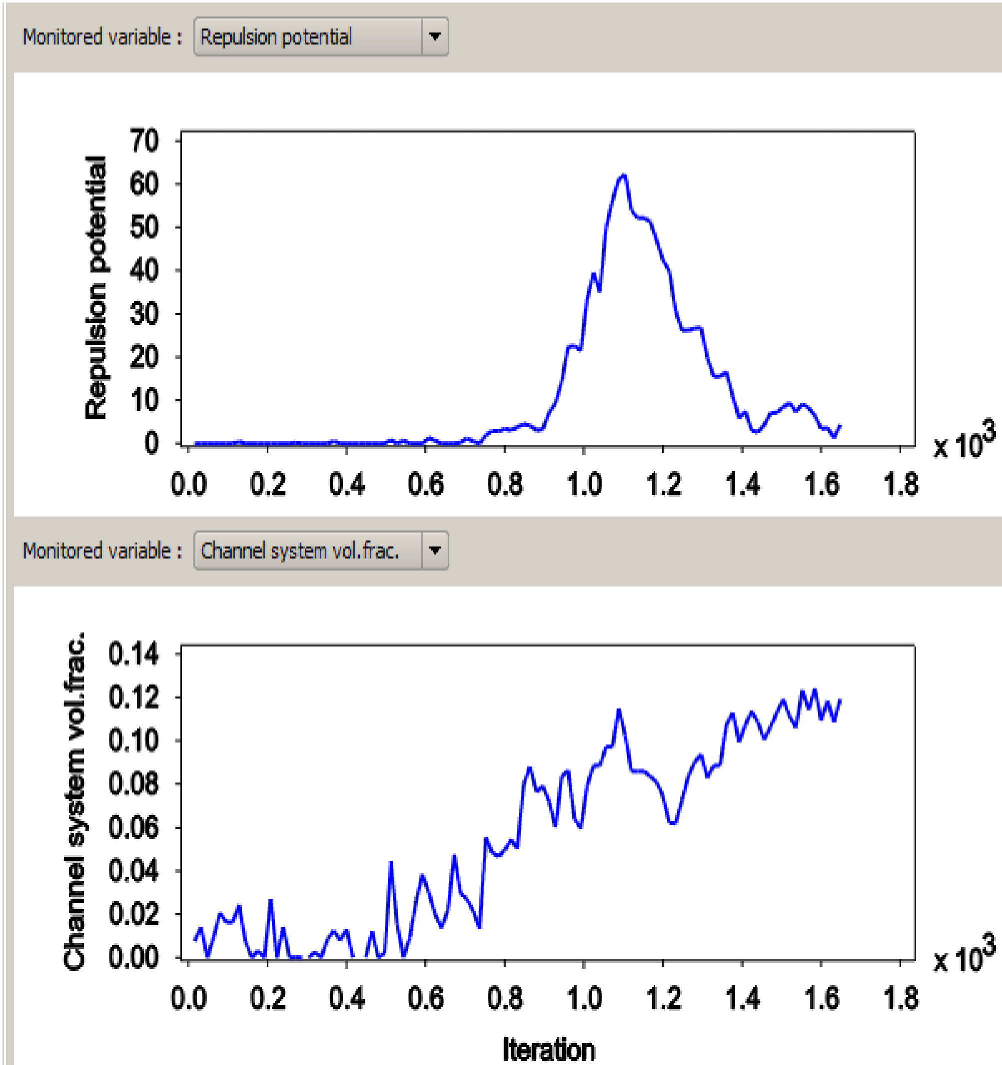
Detecting convergence problems

Interrupt panel graphs:
- Volume fractions.
- #uncond. obs.
- Repulsion potential.
- Seismic potential.

Small values good for the potentials.

If one factor gets worse while another improves, there is a conflict.

Only end state matters.



Convergence killers

- Data inconsistencies:
  - Mismatch between object thickness and well observations.
  - Mismatch between seismic and well data.
- Hard conditioning:
  - Too narrow volume fraction interval.
  - Forced well couplings that are improbable.
  - Too sharp seismic discrimination.
  - Too stiff prior geometry of objects.
  - Too strong repulsion.
- Information overload
  - Keep it simple - avoid unnecessary trends, interactions

Marked point processes is more than channels