WELL CONDITIONING IN A FLUVIAL RESERVOIR MODEL

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SUMMARY.This paper describes a method for conditioning a simulation of a fluvial reservoir on any facies observation. The channels are assumed parametrised at sections normal to the main channel direction. Projections of the observations on these sections generates a map suitable for drawing conditioning values. This map contains the information from every facies observation between two adjacent sections. Deviating and horizontal wells are easily handled. The methodology is implemented and demonstrated in an example with a complex well.

1. INTRODUCTION

Stochastic modelling of petroleum reservoirs is necessary to obtain information about the uncertainties involved, see [2]. Fluvial reservoirs are common in the North Sea. This paper describes an improved version of an approach for conditional simulations of facies in fluvial reservoirs under a model described in i.e. [1] and [4]. For examples based on this model see [5].

As wells typically are drilled deviating and even horizontal in parts, a new conditioning algorithm was necessary for this approach, since almost vertical well paths were assumed. The scope was to find an algorithm that used no assumptions on the well path, and conditioned properly on the actual locations of all facies observations. The only assumption is that the channel shape is rectangular at all cross sections through the main channel axis.

2. DEFINING A QUILT

Each channel in the simulated reservoir is parametrised along a straight line that runs through the reservoir, the main axis. The channel is discretised into a number of cross sections perpendicular to this channel axis. In each of these, the channels are considered rectangular. Four parameters are used to describe the channel at each section of the channel axis: thickness, width, horizontal and vertical displacement of the channel. These parameters are 1D Gaussian fields. The number of cross sections is inverse proportional to the shortest correlation length of these fields. When drawing a channel, conditioning points are first drawn in those sections where there are wells near the expected position of the channel. The channel is then determined by drawing four Gaussian fields in all cross sections, conditioned on these points.

Well information is projected into the sections. The resulting pattern, called a quilt, gives restrictions on the conditioning values. According to this quilt, the conditioning values for the parameters are drawn, or set if the value is unique.

The projection between the sections corresponds to the actual observations. It is called a quilt since it is a patchwork of polygons as seen below.

A quilt consists of three types of data: Areas to cover, areas to avoid and areas to touch. These types correspond to three possible kinds of observations from a well: Negative, positive and boundaries between these. Negative observations are interpreted as observations of a non-channel facies while positive observations are channel facies observations associated with the current channel.

Wells may have points that do not give any information regarding the current channel. Such points are missing values and observations of other channels. These are ignored in the conditioning since they do not influence the actual drawn channel location.

The quilt is made from one section to the next, by projecting all the wells that lie between them. The projection is made as a linear projection from the channel corners through the well points. Every point projected will give rise to a rectangle in the quilt. The quilt for a single observation between two sections is shown in Figure 1.

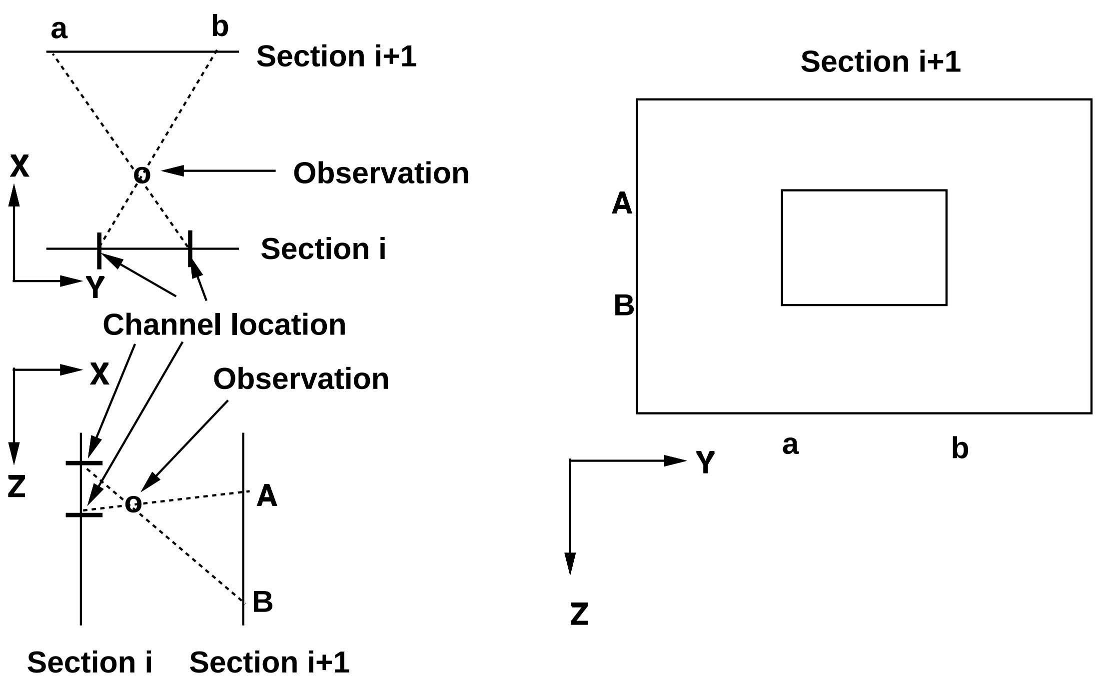

FIGURE 1. Making a quilt for one observation location. Projections are drawn from the corners of the channel in Section `i` through the observation into Section `i+1`.

When drawing the first channel location, this scheme can not be used as there are no channel corners to project from at that stage. Normal projections are therefore used, giving points in the quilt. Since points are considered degenerated rectangles, the conditioning can be made similar to every other quilt, it is only the quilt that is different.

All points where the observation status changes must be projected. Except from that, the well path is discretised into a number of points between which it is said to be linear. All these points are projected. Projections from all other points are then given by linear interpolation.

The projection of a positive observation gives information about where the channel must be. If the observation in Figure 1 is considered positive, the rectangle in the quilt must be at least partially covered by the drawn channel in that section. Projections from the lower left corner of the channel will give the upper right corner of the rectangle in the quilt. As long as the lower left corner of the channel stays below and to the left of this rectangle corner, the observation point is not below or left of the channel. The same argument holds for the upper right corner. The quilt therefore holds the information of where the lower left and upper right corner of the channel must be, see Figure 2. These areas are restricted by the maximum channel dimensions. For multiple positive information, it is still sufficient to have the channel intersecting all positive rectangles. Note that the linear interpolation of the well path causes no problem here; if two points are inside a rectangle (the channel), the straight line between them is also inside.

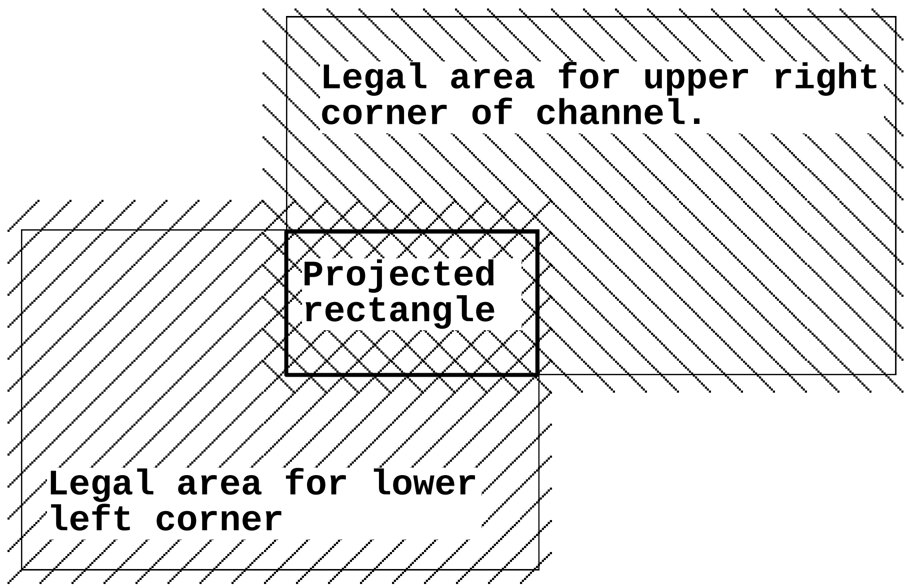

FIGURE 2. Quilt data from a positive point. Note that the projected rectangle is legal for both corners.

For negative observations, the channel must not cover the projected rectangles. In addition, the area between two consecutive negative rectangles must not be covered by the channel, since this area is the projection of the linear path between them, see Figure 3. Each draw of channel parameters are tested against these areas to check validity of the draw as they are not easily directly conditioned on.

The observation of a boundary will in the quilt be given as a rectangle whose edges the channel must touch, but not intersect. A facies change is information on both positive and negative areas. As the boundary point is not inside the channel, the projected rectangle is a negative area. However, using the same reasoning as for the other points, it turns out that the channel must touch one of the edges.

When a quilt contains boundary rectangles, it is analysed to find which kind of channel edges (top, bottom, left or right) the boundaries represent. The first step is to look at the direction of the negative area of the well after the boundary. If the well goes up and to the left, the boundary must be a channel top or left

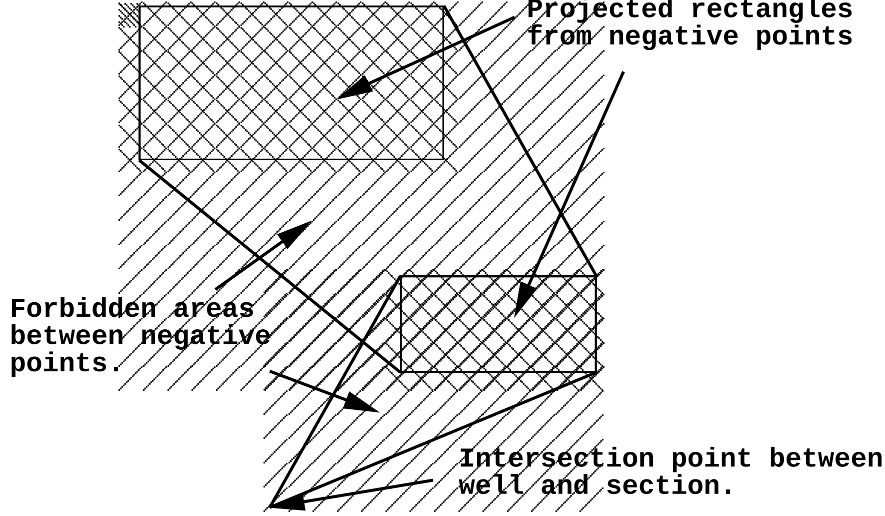

FIGURE 3. Quilt data from three negative points along one well between two sections.

edge, and so on. Then, if there are several boundaries, illegal combinations of edges are ruled out. If there are no legal combinations left, the quilt is illegal and the complete channel must be redrawn. When there are remaining combinations, one is drawn according to their relative probabilities.

Knowing which channel edge the boundaries represents is equal to knowing which edge of the projected rectangle the channel must touch. This gives constraints on the location of the lower left and upper right corner points, and is stored as such.

4. CONDITIONING ALGORITHM

To generate channels according to the quilt, a Metropolis-Hastings algorithm is used, see [3]. This is done because it is too difficult to draw correctly conditioned on a quilt directly, and even if this was done, well information is not used correctly when placing the channel (location of main axis, mean width and thickness, and so on). Instead, a potential is generated from the drawing, and channels are accepted or rejected according to this potential. Note that in order to achieve convergence, it must also be possible to remove channels.

The first parameters to draw for a channel are its main axis parameters. Observations that may or certainly will influence the channel are identified and collected in a list. The main axis is then drawn on basis of these observations. Next, the first section where the channel is conditioned is decided, see Figure 4. It is drawn among the possible sections adjacent to a specific type of observation. The type used is the one existing with most information about where the channel location is. If several holds the same information, one is drawn uniformly.

After this, a direction is chosen, and the well conditioned sections are then drawn starting in the current section and moving in the given direction. Sections are drawn sequentially as long as they contain positive (or boundary) observations.

When drawing in a quilt, all positive information is used to truncate the distributions. Possible channel locations are then drawn until a legal location is found. This generates a potential proportional to the number of draws used to find the location, and the probability area that has been truncated.

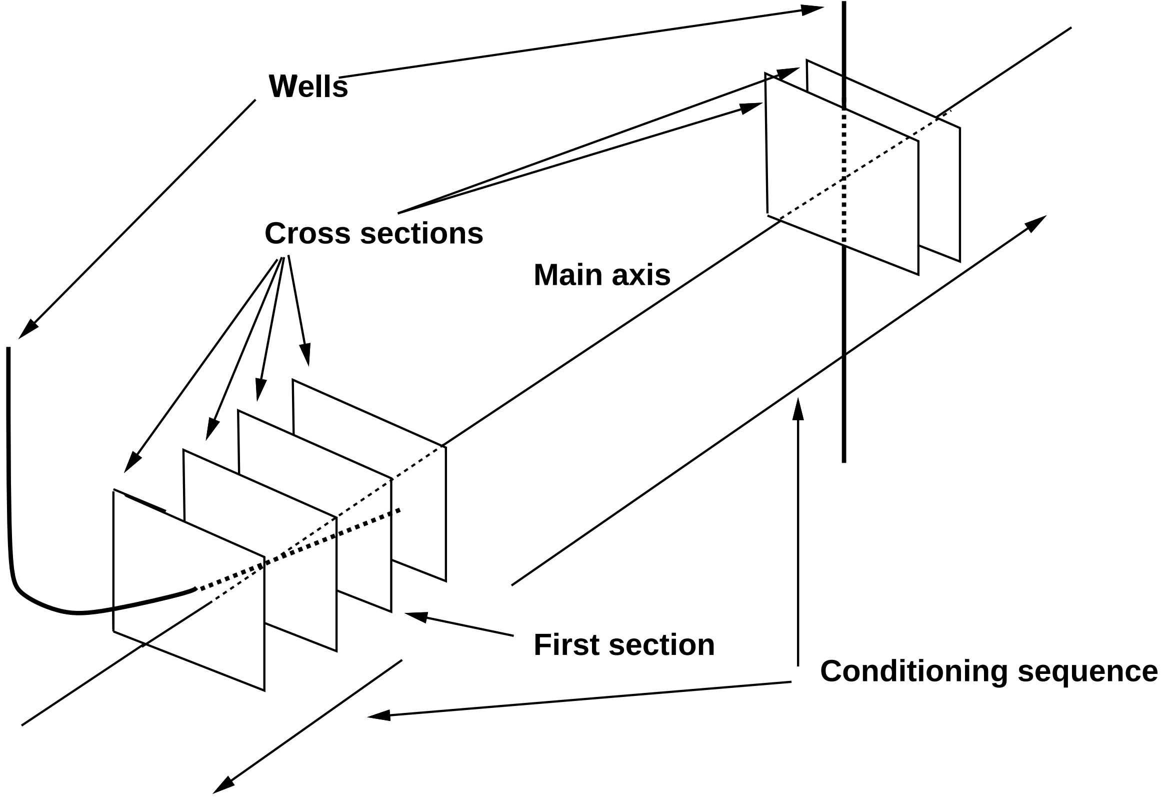

FIGURE 4. The well cross sections are normal to the main channel belt axis. The channel belt is first drawn in one well cross section and then sequentially in each direction.

If a section contains only negative information, a quilt is made from the current section to the next section with non-negative observations. Values are then drawn in this section before the sections in between are drawn. The purpose of this drawing procedure is to make sure that the channel path passing the negative observations is corresponding to the positive observations.

When there are no more sections with non-negative observations, channel conditioning points are drawn for remaining sections with negative observations. The current section is then moved back to the starting section, the direction is changed, and the rest of the channel is drawn in the same way.

The distribution for conditioning points in a section should be conditioned both on the quilt and on all other conditioning points inside the correlation distance which are already drawn. As this would be very computer intensive, only the conditioning points in the nearest sections on each side are used. This is correct if no wells are seen in more than two sections, and the wells are further apart than the correlation distance.

After all the conditioning points are drawn, the Gaussian fields for horizontal and vertical displacement, width and thickness are drawn conditioned on these between the conditioning sections. Finally it is checked that the actual drawn channel is in accordance with all the observations, not only those in the neighbourhood near the channel that were included in the list used for the channel drawing.

5. EXAMPLE

As an example of this algorithm, channels have been conditioned on a complex well. A cross section through the well is shown in Figure 5. Dark areas of the well are background facies, light are channels. The algorithm correctly places channels in the observations; the small discrepancies seen are due to the reparametrisation of channels into a regular grid. The cross section is parallel to the mean channel direction.

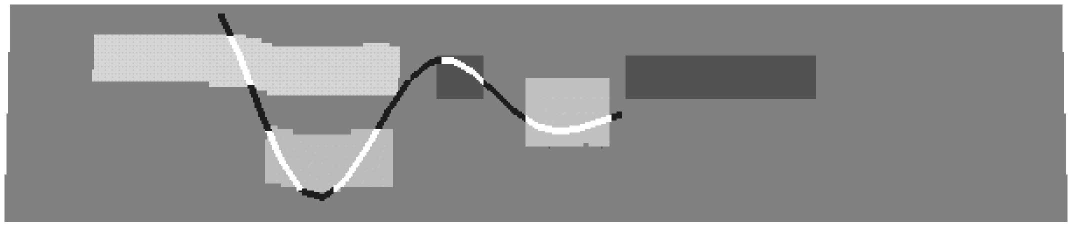

FIGURE 5. Cross section through well.

6. CONCLUSION

Using the channel parametrisation described here, the quilt gives a true map of possible channel locations. The conditioning has also been extended by including crevasse observations. This gives more information in the quilts.

By using a Metropolis-Hastings algorithm, it is possible to draw channels conditioned to the quilts, and thereby honour well observations exactly within an object based model.

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