

# A Petrel Plugin for Ranking Realizations

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*A large number of realizations can be created relatively quickly with geostatistical tools such as the Petrel modeling software. Flow simulation of all the realizations is challenging because of computational time requirements. Often, a limited number must be selected for input to flow simulation. Selecting the first realization or selecting them randomly may lead to unusual low or high results and does not permit an assessment of uncertainty. The realizations are ranked according to some simple measure that (ideally) is highly correlated to the flow response variables of interest. A new static ranking measure of quality  $Q_s$  is proposed. A Petrel plugin is presented to calculate  $Q_s$  from three-dimensional realizations of cell volume, porosity, permeability and water saturation. This allows Petrel users to rank realizations in Petrel and select representative ones for flow simulation.*

## Introduction

Reservoir performance prediction usually involves a two-step process: static property modeling and flow simulation. Geostatistical techniques are used to build static property models based on all available data. A large number of realizations may be created quickly to assess uncertainty, but in practice, only a limited number of realizations will be chosen to perform flow simulation because of the computational limitations. Randomly choosing a limited number of realizations will not accurately represent uncertainty. Ranking could be used to select these models which will produce expected and bounding flow results <sup>[1]</sup>.

Ranking realizations by original or connected hydrocarbon (oil or gas) in place (OOIP or COOIP) is a reasonable first approximation. The next refinement is to consider where the producing wells will be located. Only the cells connected to producing wells are counted. Experience has shown that including additional modifying factors improves the correlation between the ranking measure and important flow responses. Distance from the production wells is one parameter. Permeability is an important parameter for oil production; higher permeability permits higher production rates. These factors (and others) can be used as modifying factors in the calculation of COOIP.

The goal of this paper is to present a plugin for Petrel that does ranking. The current version of Petrel, or most other commercial software, does not allow the user to explicitly perform ranking. Since ranking method can help to choose which realizations for flow simulation and Petrel is popular in oil industry, we felt it was important to make a plugin for ranking.

## Static Quality for Ranking

The static quality,  $Q_s$ , for a particular realization is calculated as follows:

$$Q_s = \sum_{iw}^{nw} \sum_{j=1}^{n_{iw}} V_j \cdot \phi_j \cdot (1 - S_{w,j}) \cdot \left( \frac{d_{\max}}{d_{j,iw}} \right)^{dw} \cdot \left( \frac{k_{j,iw}}{k_{\max}} \right)^{kw} \quad (1)$$

Where  $Q_s$  is the static reservoir quality for a particular well distribution and geological model,  $n_w$  is the number of producing wells,  $V_j$  is the volume of cell  $j$  that is close to well  $i_w$ ,  $\phi_j$  is the porosity of cell  $j$ ,  $S_{w,j}$  is the water saturation of cell  $j$ ,  $d_{j,iw}$  is the distance of cell  $j$  to well  $i_w$ , and  $k_{j,iw}$  is the geometric average of the permeability from cell  $j$  to well  $i_w$  in the shortest path. For simplicity of notation, the realization number is not indexed in Equation 1.

The ranking steps can be summarized as follows:

1. Multiple realizations of porosity, permeability and water saturation are assembled, and then the NTG

- parameter will be got according to the cutoff values of effective reservoirs.
- Calculate geo-objects (Connected three-dimensional bodies). The connected cells have the same geo-object number. Fig.1 shows two geo-objects, and they are separated by non reservoir.
  - Sequentially select an unsampled cell  $j$ .
  - Judge NTG of the cell  $j$  is 1 or 0. If it is 0, then go to step 3. Otherwise, go to next step.
  - Find out the well  $i_w$  which is closest to cell  $j$ . Judging if the well  $i_w$  and the cell  $j$  are connected, if they are not connected, finding out the second closest well and then do same judgment. Otherwise, go to next step. Taking cell  $i$  as an example, the closest well to the cell  $i$  is the well  $i_w$ , but they are not connected, so the well  $j_w$  will be selected.
  - Calculate the shortest distance between the well  $i_w$  and the cell  $j$ , and calculating the geometric average permeability along the line of sight from the well  $i_w$  and the cell  $j$ . As showed in fig.1, although the distance between cell  $k$  and well  $i_w$  is same with the distance from cell  $j$  to well  $i_w$ , the geometric average permeability along the line from one cell to one well is different because of the exist of shale zone. The cell  $j$  would be more important than the cell  $k$  on the contribution to well  $i_w$ .
  - Calculate the  $QS$  for the well  $i_w$  and the cell  $j$ , then repeat step 3 to 7 till the  $QS$  for last cell is calculated.
  - Rank realizations based on  $QS$ .

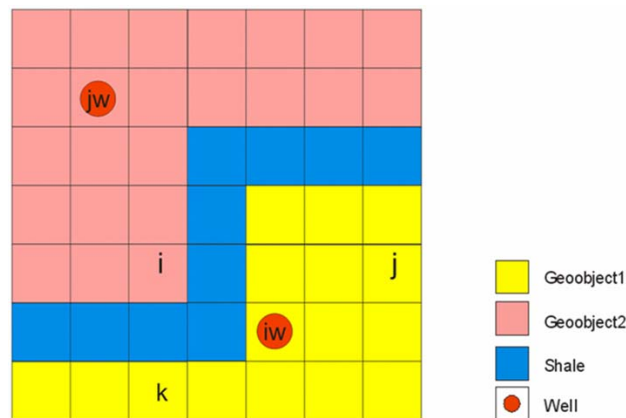


Figure 1: geo-object

### Petrel Plugin Basics

Schlumberger Information Systems released an application programming interface (API) for Petrel called Ocean. Ocean gives end users of Petrel the ability to add their own custom algorithms and processes right into Petrel. It means that we will not need to export data, reformat it, run the new algorithm from the command line, and import the results.

Ocean allows plugins access to many of the native Petrel data and object types. All of them can be read, some existing objects can be modified and other object types can be created. Ocean even allows custom objects to be defined and saved in Petrel.

We can build a plugin only using C# and Ocean. In this case, we already have programmed FORTRAN codes to perform ranking, so we can use a simple way to make ranking plugin. That is some FORTRAN codes can be compiled as DLL, then it can be called by an executable or another DLL. In this way we can reduce some repeated programming work.

### Geo-object DLL

The first stage of the plugin development was to convert the ranking from stand-alone programs to DLLs. The DLLs will then be called from the Ocean plugin. In addition, there will not be any errors introduced by translating from FORTRAN to C#. In this case, only the part of calculating geological objects FORTRAN codes is compiled into DLL, calcgo.dll. The DLL can be called from an executable or another DLL. When the DLL is called, a set of arguments must be passed from the calling program. The arguments include input data for the DLL, parameters for running the algorithm within the DLL and arguments for the DLL to return to output to the calling program.

The code exporting the calcgo subroutine within the DLL is below. It lists the input and output arguments and what they are. The arguments can be real or integer, single values or arrays. The arguments passed to the DLL must be exactly the same as what the DLL is expecting for it to work right.

```
subroutine calcgo(nx,ny,nz,MAXX,MAXY,MAXZ,net,geobj)
!DEC$ ATTRIBUTES DLLEXPORT::calcgo
!DEC$ ATTRIBUTES ALIAS: 'calcgo'::calcgo
integer, intent(IN) :: nx,ny,nz,MAXX,MAXY,MAXZ

integer, intent(IN) :: net(MAXX,MAXY,MAXZ)

integer, intent(OUT) :: geobj(MAXX,MAXY,MAXZ)
```

For example, the input to the DLL is passed in 1 three-dimensional arrays, net, and 6 integers. The output is one three-dimensional arrays, geobj. The purpose of this DLL is to calculate connected geological objects, and the more details can be found in reference <sup>[2]</sup>.

### Calling DLL

The Petrel plugin is the data handling and interface for the ranking processes. It gets the required input from the user, reads the data from Petrel, calls the DLL, receives the output from the DLL, and displays the ranking results.

The input from the user includes data sources and program parameters. The plugin will then read all of the input data from the different Petrel objects. Any data formatting or conversions are done inside the plugin. Then the plugin will call the DLL and pass it all of the required information. The C# code for setting up the plugin-DLL link is:

```
class calcgeobject
{
    [DllImport("calcgo.dll")]
    public static extern void calcgo(
        [MarshalAs(UnmanagedType.I4)] ref int nx,
        [MarshalAs(UnmanagedType.I4)] ref int ny,
        [MarshalAs(UnmanagedType.I4)] ref int nz,
        [MarshalAs(UnmanagedType.I4)] ref int MAXX,
        [MarshalAs(UnmanagedType.I4)] ref int MAXY,
        [MarshalAs(UnmanagedType.I4)] ref int MAXZ,
        [MarshalAs(UnmanagedType.LPArray)] int[, ] net,
        [MarshalAs(UnmanagedType.LPArray)] int[, ] geobj);
}
```

The order of the arguments is exactly the same as the order shown in the Fortran DLL above. This lets the C# Petrel plugin know exactly what arguments need to be passed to the DLL. After the subroutine in the DLL is finished, it will return the output from the run to the calling program. The order of array is different between FORTRAN and C# and Chald discusses this in detail <sup>[3]</sup>.

### Plugin Details

The ranking plugins can be run via the process menu or the workflow manager in Petrel. Double-clicking on the plugin in the process menu or in a workflow opens the user interface. Figure 2 shows how the plugins are access through Petrel. Figure 3 shows the ranking user interface.

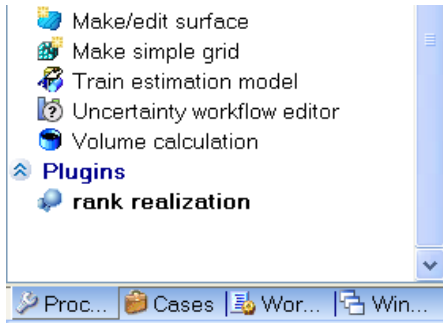


Fig. 2 Access ranking plugin

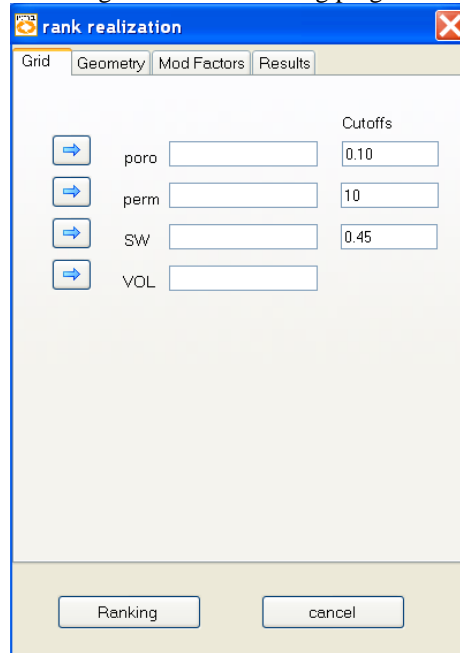


Figure 3 User interface in petrel

The ranking user interface includes 4 tables. The first one allows users input data from Petrel, including porosity, permeability, water saturation and cell volumes. These data can be input by selecting an object and clicking the blue arrow. In addition, users need to set the cutoffs value of porosity, permeability and water saturation in order to calculate net reservoir. In the current version, users need input porosity realization first and different property simulation realizations must be stored in a sub fold separately (As showed in figure 4). If you do not do like this, the program will be end abnormally.

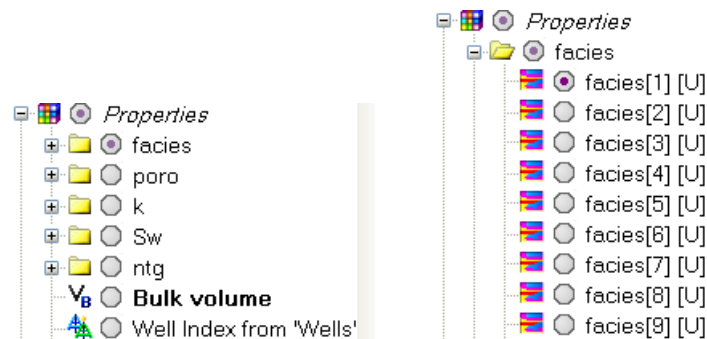


Figure 4 Realizations of different properties store separately in different folds

The ranking plugin is flexible that allow users only choose a part area of model and/or only a part wells to calculate Qs and rank results. Sometime we are only interesting in a particular area of model and wish rank realizations only based on selected area. In order to do this, a closed polygon needs to be built first and then drop it in input windows.

You can easily create a polygon using make/edit polygons tool under utilities process and make sure that polygon is closed. As showed in figure 5, we can drop selected polygon into limit polygon box in geometry table using blue arrow. When a limit polygon is chose, all the cells outside the polygon will not be calculated. This provides user ability to access any special part of research area.

Sometimes we may want to rank the modeling results based on different wells combination or some planning wells. First, we need to build a wells index model which only includes wells that we want. As showed in figure 6, a wells index model can be built using well index method under geometrical modeling process. You need choose only visible wells only option and then the well index model will only include the wells that you make them visible in current window. As showed in Figure 7, for example, the index well model only includes three wells, B1, B2 and B5. After establish well index mode, we drop it into well group box in geometry table. When well group is chose, only the wells in well group will be calculated.

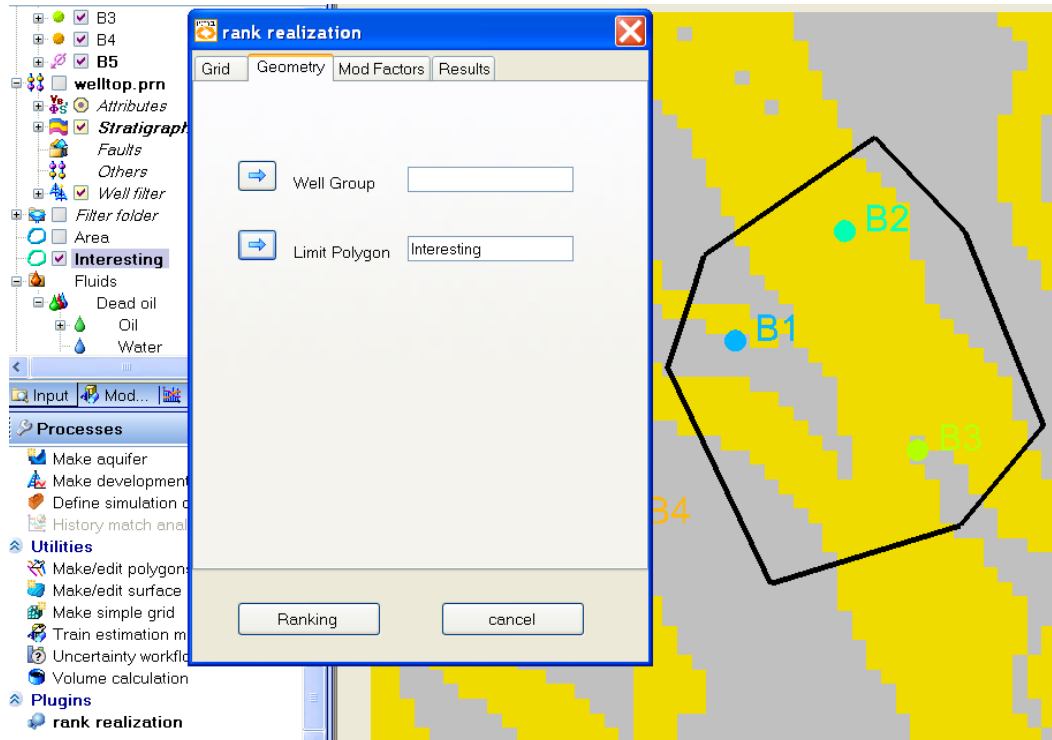


Figure 5 Set polygon limit

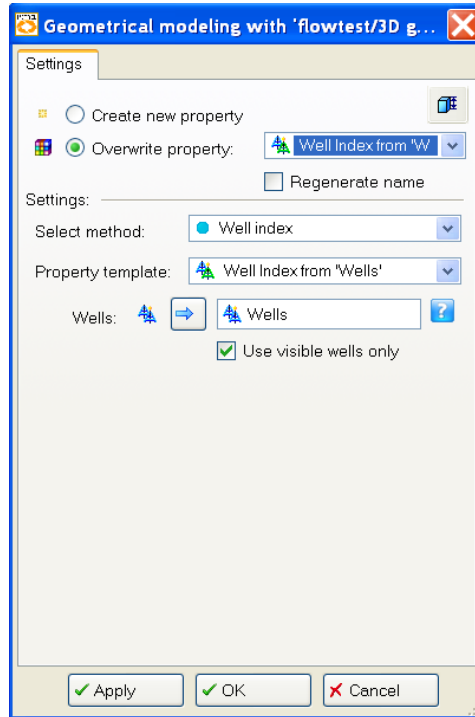


Figure 6 Set polygon limit

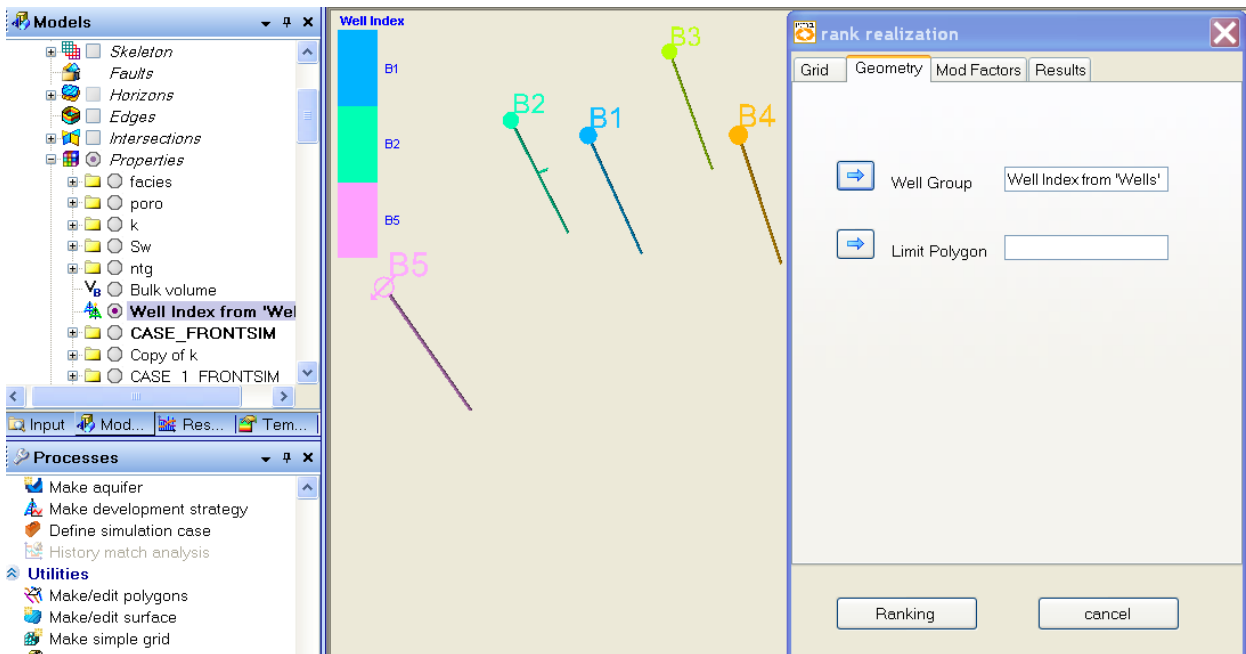


Figure 7 Set wells group

The ranking algorithm is flexible. As showed in equation 1, there are two weights,  $dw$  and  $kw$ . The parameter  $dw$  controls how many difference between far cells and near cells to a special cell when calculate  $Q_s$ . The parameter  $kw$  controls the effect of permeability on  $Q_s$ . The value of weights is bigger and the effect on  $Q_s$  is greater. There are also maximum value for distance and permeability. The cells which are beyond the max distance to a special cell will not be considered when calculate  $Q_s$ . The permeability maximum is to avoid that a few extreme high permeability have too much effect on  $Q_s$ . If the  $dw$  and  $kw$  are 0, the  $Q_s$  will equal to connected oil volume.

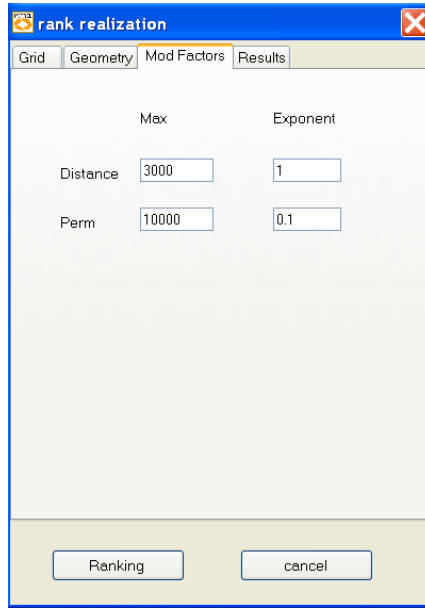


Figure 8 Set some factors

The output from the ranking plugin is a table which includes the realization number, ooip value and ranking sequence, cooip value and its ranking sequence, Qs value and its ranking sequence. An example ranking result is showed in table 1. From this table, we can select typical realizations for flow simulation.

Table 1 Ranking result

Number	OOIP	IOOIP	COOIP	ICOOP	QS	IQS
1	1494.23	33	843.36	15	317.3	16
2	1302.53	24	907.86	22	357.58	25
3	2060.05	50	1718.72	49	592.59	49
4	1348.67	25	1137.07	37	427.34	37
5	1716.06	43	910.34	24	336.71	22
6	1470.91	32	736.42	11	283.08	11
7	996.19	4	498.22	2	202.37	2
8	1884.99	48	1540.14	45	542.93	45
9	1434.14	29	1307.84	41	490.83	42
10	978.19	3	685.68	8	274.95	8
11	1570.55	37	983.27	27	362.11	26
12	1242.2	19	1117.43	36	411.7	36
13	1754.99	44	865.49	18	324.58	19
14	1835.33	46	1598.83	47	577.26	48
15	1227.65	18	1031.76	32	400.42	35
16	1682.23	41	1273.01	40	459.26	39
17	1132.95	10	995.69	28	389.31	33
18	1467.3	31	1225.59	39	459.77	40
19	1193.92	14	970.64	26	377.84	29
20	1665.14	40	1556.51	46	552.03	46
21	1255.26	21	897.93	21	333.54	20
22	1842.44	47	1632.55	48	562.87	47
23	1767.59	45	1046.5	33	382.73	31
24	740.61	2	510.98	3	209.91	3

25	2043.24	49	1866.92	50	651.72	50
26	1206.22	16	879.77	19	312.53	13
27	1088.69	8	653.54	6	261.36	7
28	1695.73	42	1437.46	43	524.74	44
29	1463.2	30	1012.97	29	354.56	24
30	1513.13	35	1218.52	38	457.45	38
31	1290.27	22	717.6	10	280.41	10
32	1560.13	36	1018.63	31	366.57	28
33	1295.85	23	964.23	25	363.77	27
34	1196.94	15	811.56	13	321.68	18
35	1192.18	13	562.92	4	215.09	4
36	1499.13	34	1105.73	35	391.62	34
37	489.26	1	305.99	1	128.96	1
38	1184.43	12	883.35	20	321.44	17
39	1058.17	5	697.75	9	275.42	9
40	1402.19	27	863.6	16	313.33	15
41	1225.59	17	909.92	23	339.04	23
42	1610.79	38	1353.56	42	488.26	41
43	1405.19	28	1017.43	30	380.97	30
44	1115.88	9	804.63	12	313.2	14
45	1243.27	20	1091.22	34	387.47	32
46	1067.68	6	616.99	5	246.22	5
47	1374.43	26	816.92	14	297.91	12
48	1075.05	7	864.69	17	333.76	21
49	1659.48	39	1467.76	44	524.2	43
50	1159.27	11	681.3	7	255.09	6

## Conclusions

Using Ocean, the ranking routines have been written into a Petrel plugin. Ranking can make choose of realizations easy and allow petrel users select representative realizations for flow simulation.

## References

- [1] C.V. Deutsch and Sanjay Srinivasan (1996) Improved Reservoir Management through Ranking Stochastic Reservoir models. SPE 35411.
- [2] C.V. Deutsch. (1998) FORTRAN Programs for Calculating Connectivity of Three-dimensional Numerical Models and for Ranking Multiple Realizations. Computers & Geosciences 26(1), 69-76.
- [3] C. Neufeld and C.V. Deutsch. Programming Tips for Plugins. In Centre for Computational Geostatistics, Paper 402, Annual Report 9, 2007.