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Why Ranking is Still an Important Problem?

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Twenty years ago practitioners in geostatistics were looking forward to an exponential increase in computer-power to perform flow simulations in seconds; thus, the need for ranking and selecting realizations would disappear. After all these years, with the rapid growth of technology and the presence of that computing power, the flow simulators still process a realization in hours or days; processing 100 realizations is still prohibitively slow. The necessity of ranking of stochastic realizations does not seem to have disappeared. In fact, the use of $P90$*,* $P50$*,* $P10$ *models is becoming entrenched in practice. This note reviews the reasons for this and comments on the future of ranking and model selection.*

Modeling Uncertainty

Capturing the influence of geological heterogeneity on recovery is important in geostatistical reservoir modeling. The concept of generating stochastic realizations has been around for a while. They permit transferring geological uncertainty through recovery performance predictions (Journel and Alabert, 1990). Not all uncertainty in reservoir modeling is associated with incomplete data. For example, uncertainties resulting from different scales and reproduction of non-linear complex geologic features may not be represented by a few realizations. Journel and Alabert (1990) proposed the quantification of geological uncertainty with a large number of stochastic realizations. For a consistent investigation of reservoir performance, the uncertainty should be transferred to the performance parameters such as oil production rates, water production and water injection. This would require a comprehensive flow simulation on every realization. However, back in the Eighties a comprehensive flow simulation on so many realizations was impossible.

Ranking

The idea of ranking was processed by Journel and published by Ballin and coauthors in the context of stochastic reservoir modeling (Ballin et al., 1992). Deutsch and Srinivasan (1996) describe ranking as a method that selects the realizations that span the production uncertainty. A number of ranking schemes have been presented in the same paper and the corresponding limitations were discussed accordingly.

The concept of ranking becomes important when the realizations should be processed for uncertainty management. In other words, ranking is a tool to reduce the number of realizations to be processes further. It is important to realize that realizations are generated by stochastic simulation and no realization is ``better'' or more probable than others. This explains that criteria which is applied to rank the realizations is largely crucial to the final understanding and decision making (Deutsch, 2002).

Ranking considers a simplified transfer function that permits selecting a few realizations for further studies of the reservoir performance (see Figure 1). Realizations are generated to be equally likely to be drawn, but some would perform better than the others due to the details of the particular realization; some realizations have more high quality reservoir intervals than others. The ``true'' reservoir is unknown and the realizations are constructed to provide an estimate of uncertainty. The flow simulator is applied to the realizations to understand the uncertainty in production variables due to geological uncertainty.

Performing flow simulation on all realizations is a time-consuming process. A relatively simple transfer function that could approximately identify the rank order of every realization based on a quick measurement is still of interest (Fenik et al., 2009). For example Cruz and coauthors proposed the quality map as an alternative for reservoir uncertainty quantification. The number of realizations along with a number of scenarios should be considered for flow simulations in order to ease the decision making process (Cruz et al., 1999). An ideal simplified transfer function would have a large correlation between the simplified ranking measure and the real production variable (see Figure 2). The performance of the simple transfer function could be examined by processing some realizations through both the simple transfer function and the full transfer function (flow simulator).

Two main types of ranking methodologies have been discussed in the literature: (1) static ranking, and (2) dynamic ranking. The static type is based on evaluation of the the volume of high quality reservoir and its connectivity and tortuosity whereas the dynamic type approximates the flow simulations using some approximate physical setups such as streamlines or a proxy model. Dynamic ranking is a more complicated procedure that employs more parameters and effort. McLennan and Deutsch argue the effect and simplicity of the static method compares to the dynamic one (McLennan and Deutsch, 2005). In the static ranking method, the key idea is to carefully calculate the local connectivity at the reservoir. They also show that among the number of ranking measures in the static type, local connectivity is the most effective measure for the SAGD drainage process. Also, a number of studies have investigated the ranking methods for the application of SAGD (Fenik et al., 2009; McLennan and Deutsch, 2005). The success of SAGD heat injectivity and gravity drainage process highly depends on the hydrocarbon connectivity of the reservoir around the wells. A reliable ranking methodology significantly reduces the number of realizations needed for reservoir management.

Ranking techniques are also applied to the real production variables under specified operating conditions. There are a number of ranking measures that help assess uncertainty quickly and permit decision making that considers the uncertainty. A reliable ranking process is essential to reservoir management with uncertainty. Decisions regarding the reservoir performance are always based on the *estimated* values and not the *true* values. All data are almost never available to the geological modeling. In this regard, the decision making often considers a loss function (Ballin et al., 1992). The loss function considers economic preferences, evaluating the cost corresponding to different decisions. The accuracy of such cost evaluations strongly depends on how precise the uncertainty has been transferred to the performance parameters and how well the ranking has been applied.

Discussion and Concluding Remarks

Ranking has been widely practiced as an important tool in post processing and reservoir management during the past decades. Much work has been done to study different criteria to select realizations. The question of ``how many realizations?'' remains critical to decision making in reservoir studies despite the fact that technology is growing quickly. Answer to this question is not simple and depends on the spatial uncertainty of the reservoir, geological and petrophysical features of the reservoir and the recovery techniques considered by the company. Of course, the best understanding of the reservoir is possible through the flow simulation of all the realizations. However, this has never been efficient and as will be discussed shortly would never be the concrete solution to reservoir uncertainty management.

Advances in computing speed has been suggested as the solution to processing multiple realizations for uncertainty assessment (Deutsch and Srinivasan, 1996). The question is that, after all these years of rapid growth in CPU technology (speed and power), why is ranking still an important part of geostatistical reservoir modeling? Also, is ranking expected to be important in the future?

From personal observation, it appears that performing the full flow simulation still requires roughly the same amount of time as in the 1980s, despite modern advances in computational capability. It must be noted that the growth in technology is not limited to a specific field, but to all aspects of science and engineering simultaneously. An important consideration that is often overlooked is that technological advances have led to realizations with larger numbers of grid cells (smaller grid sizes) and to more accurate representations of fluid and transport properties in flow simulators.

As such, despite the rapid growth of CPU technology, ranking is still a necessary practice in the study of reservoir modeling. This is because full flow simulation of all realizations remains as prohibitive as in the past, as each realization is now represented in much greater detail. This point is in contradiction to what has been suggested by some researchers -- that advances in computing power will make the necessity for ranking obsolete. In view of this, it is perhaps advisable to allocate some portion of the new computing power to develop more advanced ranking techniques, as processing every realization in the flow simulator may never be the most efficient approach. Improvements to ranking schemes can, for example, be achieved through development of simplified transfer functions that effectively transform the reservoir uncertainty to performance parameters.

We conclude that ranking will remain an important problem in the foreseeable future. The anticipated advancements in computational capacity will be used mostly to improve the spatial resolution and the details of the physics. Some geostatisticians may choose to process multiple realizations quickly at a relatively coarse resolution or with simplified physics.

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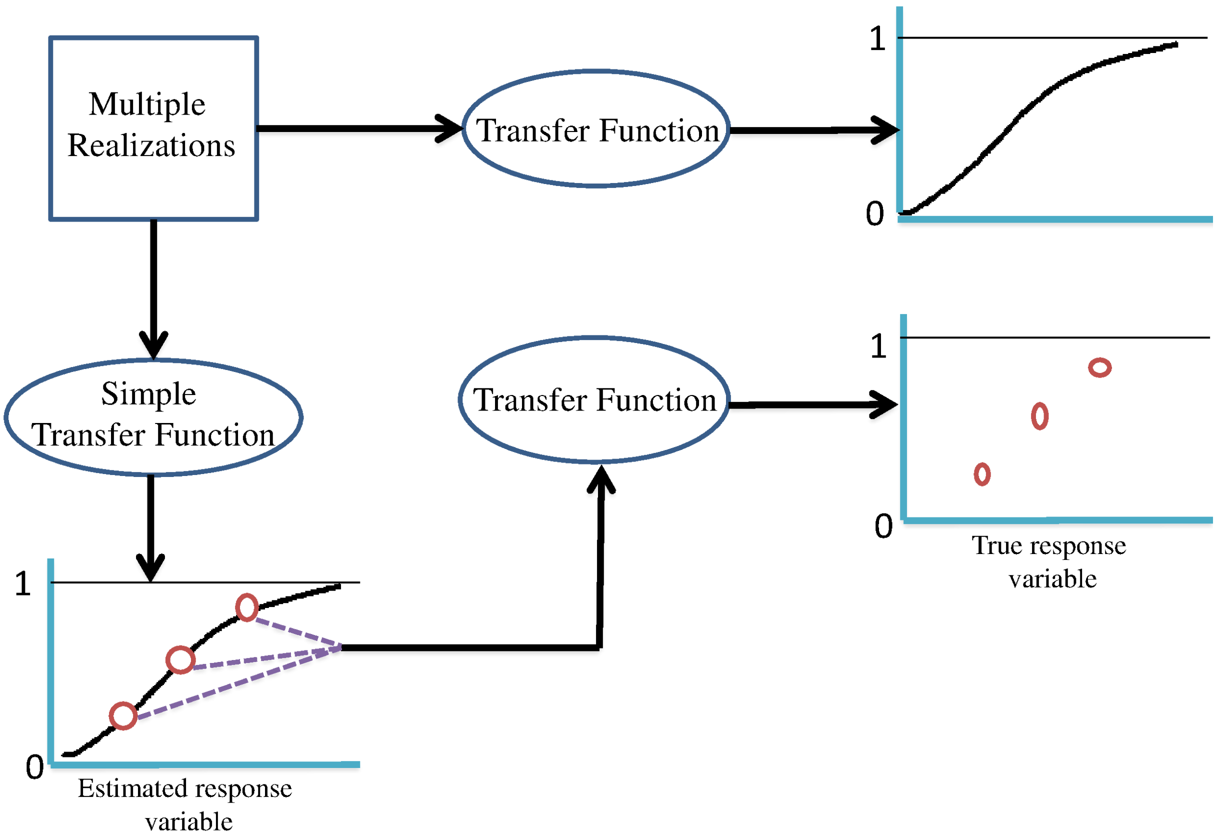

Figure 1: Illustration of acquiring the probability distribution of flow performance by applying a full flow simulation (top row) compared to a more simplified approach that results in a few realizations rather than being processed distribution of production performance.

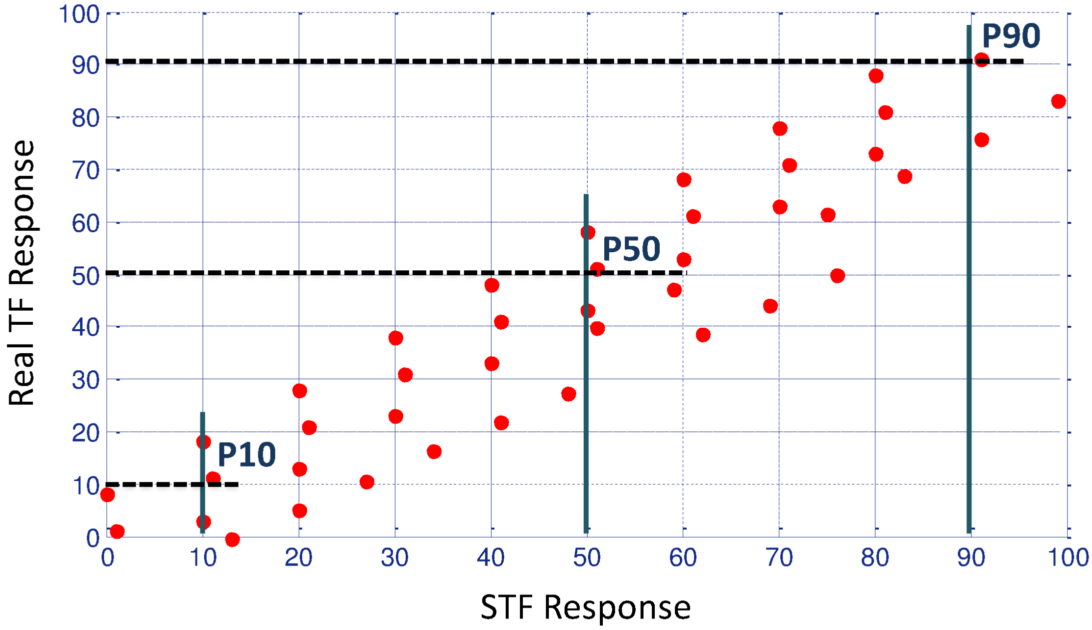

Figure 2: The correlation between the ranking after being processed by comprehensive flow simulation with the ranking based on the simple transfer function over the realizations. A reliable simple transfer function shows a strong correlation with the ranking quantiles of full flow simulation.