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How a Bayesian Approach Can Overcome Noisy Data and Interpretation Ambiguity in Automated Geosteering

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Abstract

Geosteering solves for a drill bit's stratigraphic location to optimally guide a wellbore through a target formation. Geosteering solutions focus on correlating a subject well's real-time measurements to a type log representative of the stratigraphic column. Traditionally, this is done by matching localized sections of each log with a combination of shifts and stretches applied. This is a single-solution-at-a-time approach where only the best correlation is represented, as determined subjectively by a human or via algorithmic minimization of differences between measurements (Maus et al 2020). A method that considers the full space of possible stratigraphic interpretations and assigns a complexity-related correctness likelihood to each would give geosteerers greater confidence in selecting the correct interpretation. This would be a prohibitively large space to explore via traditional optimization and inversion methods, but it is possible through application of a Viterbi algorithm to a Bayesian state space matrix.

A set of 1440 synthetic geosteering trials was generated by producing a geologically realistic layer cake, passing a well trajectory through it, and simulating realistically corrupted gamma measurements (reflecting sampling rate, calibration error, and measurement noise). This gives a true solution for accuracy comparison, and a realistic log that can be interpreted as follows: a Bayesian state space matrix is constructed which captures the likelihood of correlation between subject well and type log measurements. Prior knowledge is used to inform a state-transition probability matrix. The Viterbi algorithm is then applied to the state space matrix and state-transition probability matrix to determine the highest likelihood interpretation.

The trial data was split 80/20 into training and test sets. For the training data, three metrics were used to tune the algorithm: mean distance from true solution; misfit ratio against true solution, and algorithm runtime. On the remaining test data, highest-likelihood paths were compared to the interpretations generated by an existing residual-minimizing automated geosteering algorithm (Gee et al 2019). Performance was analyzed separately in the vertical, curve, and lateral, and solutions were spot-checked for reasonable behavior.

Compared to the existing automated method, the Bayesian method produced interpretations with comparable performance in 59% of laterals, and significantly improved performance in 34% of laterals. It also returned results 30 times faster. These results held over several sets of tuning parameters suggesting robustness. A well-tuned Bayesian algorithm has been shown to outperform existing automated methods on performance and accuracy, signifying a potential step change in the space of automated geosteering.

Viterbi is an established algorithm with many applications, but the splitting of stratigraphic mappings into a Bayesian state space and application of Viterbi is novel and allows for efficient, probabilistic solution-finding. The whole space of possible solutions can be considered, and implicitly gives solution likelihoods. The technique also accounts for the complexity of produced solutions.

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