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Maximum Likelihood & Multiple Imputation of Incomplete Static and Dynamic Reservoir Data

***W. Al-Mudhafer** (*Louisiana State University*)

SUMMARY

The problem of incomplete data is a crucial issue that should be handled efficiently for accurate evaluation and prediction in a reservoir characterization. Maximum likelihood method has been adopted to handle the incomplete data in well logs and core measurements in addition to production and injection rates of ten wells in a heterogeneous reservoir in an Iraqi oil field. Expectation Maximization algorithm (EM) is the concept of ML imputation and it starts with some initial values for the mean and the covariance matrix and iterates through imputing missing values (imputation step) and re-estimating the mean and the covariance matrix from the complete data set (estimation step). The iteration process ends when the maximum relative difference in all of the estimated means, variances between two iterations is less than or equal to a given value. Furthermore, multi-regression linear models have been set for the log porosity as a response and function of all other factors including Vsh, Gamma ray, formation density, and resistivity. Then, the core porosity has been estimated for all intervals as a function of log porosity in order to estimate the corrected permeability. These linear models have performed good quality of test indicators especially p-value, adjusted-R, and F-ANOVA.

The problem of incomplete data is a crucial issue that should be handled efficiently for accurate evaluation and prediction in a physical system. Many traditional methods have been considered to solve this problem such as listwise, pairwise, and mean substitution deletion methods. However, they don't reflect such a an efficient solution to represent the true physical system and probability of a variable's missing depends on other observed or non-observed variables leading to affect inference. These methods have no way to be considered handling the missing data in well logs and core measurement especially in heterogeneous formation as the variety of properties is too high. In this paper, maximum likelihood (ML) method has been adopted to handle the incomplete data in well logs and core measurements such as shale volume, Gamma ray, formation density, and resistivity in addition to production and injection rates of ten wells in a heterogeneous reservoir in an Iraqi oil field.

Maximum likelihood is currently considered the "state of the art" and have been considered the most robustness missing data techniques in dealing with missing completely at a random (MCAR) and missing at a random (MAR) missing values mechanisms. Expectation Maximization algorithm (EM) is the concept of ML imputation and it starts with some initial values for the mean and the covariance matrix and iterates through imputing missing values (imputation step) and re-estimating the mean and the covariance matrix from the complete data set (estimation step). The iteration process ends when the maximum relative difference in all of the estimated means, variances between two iterations is less than or equal to a given value. Furthermore, covariance and correlation matrices between each two iterations have been compared in order to get the minimum error between them and that reflects the validity of the mean substitution of missing values. Moreover, multi-regression linear models have been set for the log porosity as a response and function of all other factors including Vsh, Gamma ray, formation density, and resistivity. Then, the core porosity has been estimated for all intervals as a function of log porosity in order to estimate the corrected permeability. These linear models have performed good quality of test indicators especially p-value, adjusted-R, t-test, and F-ANOVA.

This technique has been compared with most of the other missing value handling methods such as and has shown its effectiveness and robustness to estimate the most acceptable estimation of incomplete values packages have been considered to apply these estimations. This study has been done on incomplete set of shale volume, Gamma Ray, Resistivity, porosity, and permeability for ten wells in an heterogeneous oil reservoir.