PhD Dissertation

Petroleum Engineering

A Joint Inversion and Blind Source Separation Approach Without the Need for Regularization: Applied to NMR Data Processing

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An accurate data processing algorithm is at the heart of a successful Nuclear Magnetic Resonance (NMR) log interpretation. The first step in the traditional inversion algorithm is inverting for T2 distribution from the magnetization data at a single depth. A recent innovation involves finding volume fractions of the different components (capillary bound water, clay bound water, free water, organic matter, oil, etc.) using data from multiple depths/ measurements and adopting Blind Source Separation (BSS) techniques. NMR data inversion and Blind Source Separation are both ill-posed problems. These algorithms are strongly influenced by noise and have significant error bars, especially for low values of T2.

This research develops an algorithm that utilizes a joint inversion and blind source separation approach using a new technique**,** "Kernel Incorporated Non-Negative Matrix Factorization" (KINMF). This algorithm outputs T_2 distributions and the volume fractions of different components from magnetization data by incorporating multiple measurements. This single-step, hybrid approach has a de-noising effect and generates accurate results without regularization. It significantly reduces the smearing effect that arises from standard regularization techniques and leads to one-to-two orders of magnitude improvement in processing speeds (e.g., compute time for the conventional method in a clastic system is higher than 120 sec; for the KINMF it is less than 15 sec). The algorithm was validated using forward modeling and comparison with experimental datasets. We conclude that the major impact of applying KINMF is for T_2 relaxation times less than 100 ms and significantly improved computational times (enhanced real-time data processing). This should lead to broader applicability and improved physical interpretation of the data.