Project Proposal

Purpose: Outline scope and initial milestones

Project Title

Bayesian estimation of bound fluid fraction from NMR relaxation

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Description:

The relative proportions of bound and free fluids in porous materials reveals a great deal of information about the material in a range of applications including brain imaging and mineral exploration. Classically an entire distribution (1D or 2D) of relaxation times is estimated, and the relaxation times above and below a certain threshold are considered to correspond to free and bound fluids respectively. But estimating the entire distribution is an ill posed problem, particularly when, as is often the case, the signal to noise ratio is low. It is also unnecessary if the bound fraction is the only required information.

In some situations, prior information regarding the distribution is available, and this information can be utilised to enhance the accuracy of the estimation process.

This project will implement, refine and evaluate a proposed Bayesian method of found fluid fraction estimation.

An basic understanding of signal processing, Bayesian statistics are required, and Matlab or Python programming.

This work is of interest to Schlumberger Doll Research.

Introduction:

Magnetic resonance imaging involves gathering relaxation times to acquire the nature of what is being tested. Often this is done through estimating the entire distribution of these relaxation time with signal processing techniques. Unfortunately, this is typically an ill-posed problem for use cases in which the signal to noise ratio in low. This is problematic in certain bound and free fluid detection use cases set in noisy environments. These complications require algorithmic techniques

in order to compensate for the uncertainty to give useful distribution. This project aims to evaluate and implement a new algorithmic technique and to compare with the major techniques in the literature.

The Problem:

An magnetic resonance image will gather a series of relaxation times of agitated atoms in a system. We are specifically focused on the T2 relaxation times for fluids in environments where the signal to noise ratio is low. These relaxation times gathered can be modelled as a series of exponential functions with different time constants. These time constants are the goal relaxation times for the process to find. Finding the distribution of these relaxation times is an ill posed problem due to the large effect noise can have on the data. Increasing the strength of the signal can be impractical due to power consumption and heat radiation of the subject. This diminishes the accuracy enough to invalidate simple inversion processing techniques.

Since the data is known to be a a set of linearly combined decaying exponential functions, information such as the exponential shape can be used to invert the measured data into a distribution of T2 relaxation times.

Proposed Solution:

Bayesian statistical techniques allow prior information to be incorporated into the estimation process, and hence improve the accuracy of the estimated distribution of T2 relaxation times. This project proposes an implementation of this solution where the prior is based on high SNR measurements, while the the measured data is obtained in a low SNR environment.

Therefore, the deliverables of the project will be as follows: 1. Implementation and evaluation of the competing algorithms and techniques for finding distributions of T2 relaxation times. 2. Implement and evaluate at least two new algorithms involving the implementation of Bayesian statistical techniques to establish the distribution of T2 relaxation times. 3. A bibliography of the signal processing techniques implemented for this project's solution.

The milestones of this project would be as follows:

Date (Week of)	Task
14/05/2018	Draft Preliminary Report Completed
04/06/2018	Preliminary Report Completed
25/06/2018	Competing Algorithms Implemented and Evaluated
16/07/2018	Midway Project Presentation Delivered
17/09/2018	Proposed Algorithm Implemented and Evaluated
24/09/2018	Draft of Final Report Completed
01/10/2018	Project Snapshot of Deliverables Completed
15/10/2018	Final Report Completed
12/11/2018	Final Presentation Delivered

Evaluating the Solution:

The solution is evaluated with two different types of data sets:

1. Simulated data with known T2 relaxation times to give a constant to measure the intrinsic accuracy of the algorithm.
2. Nuclear magnetic resonance (NMR) data of thirty known samples to give a practical implementation of the algorithm. This would also be associated with their theoretical distributions as well.

For data set 1 The algorithm will be implemented to measure the bias and uncertainty of the known distribution with the acquired distribution of the algorithm and competing techniques. Also the difference between the two distributions can be quantified. For data set 2, cross validation is to be used to acquire the average accuracy of the algorithm with practical data subject to a properly applicable environment.

Resources Required

This project requires: * Access to the thirty data sets to allow for assessment of the practical implementation of the algorithm.