Technology Strategy Board
Driving Innovation

Knowledge Transfer Network
Industrial Mathematics

Knowing it backwards

ITERATIVE DECONVOLUTION METHOD FOR WELL TEST DATA

Paradigm / OCCAM, University of Oxford

The need

Reservoir engineers must have sufficient information about the condition and characteristics of the well to adequately analyse reservoir performance and to forecast future production under various modes of operation. The condition of the oil well and several important reservoir parameters can be estimated from the well test data.

In analysing pressure transients recorded during the testing of a well, a deconvolution method can extract from the actual well response an equivalent single rate pressure response that usually varies smoothly in the absence of noise in the test data.

The aim of the project was to improve Paradigm's deconvolution algorithm in the presence of noise.

The outcomes

The existing deconvolution technology used by Paradigm finds the pressure response by minimising a cost function with a piecewise linear approximation of the pressure response. It often provides an unreasonable and nonphysical result when the noise in the pressure and rate are significantly high.

In a real-world situation, the total production is measured with much higher confidence compared with individual pressure and rate. Honouring this constraint will make the resulting deconvolution more realistic.

The existing deconvolution algorithm was improved and used in the analysis of the pressure transient data to smooth out the response so that it appears more like a physical response (i.e. continuous) rather than a non-realistic representation. This was also the main objective of this internship.

In addition, a total production constraint has also been introduced to ensure that any rate adjustments conform to real-world expectations.

"… we were extremely pleased at the amount of progress that Lian made over a relatively short period of time. He also showed a great deal of initiative in looking at the problem using a number of different approaches and we are very satisfied with the results he achieved."

Ralph Stadie, Paradigm

Technical summary

Using a piecewise linear approximation of the impulse derivative and the *maximum a posterior* method under a Bayesian framework, the deconvolution problem is transferred into a nonlinear total least squares (TLS) problem. A cost function that considers pressure misfits, rate misfits, total production misfit and a smoothness penalty is derived analytically. For most synthetic and well testing problems of short duration, excellent results can be achieved by solving the TLS problem directly. However, for real-world problems with long test durations, the numerical algorithms suffer from slow convergence due to the large dimensionality.

Using the special features of the cost function in the TLS problem, an iterative method is formulated using a Coordinate Descent Method. During each iteration, an approximation to the cost function is minimised to initialize the next stage. The method is efficient in computation time and avoids the ill-conditioned Jacobi matrix caused by the derivative of the total production misfit. This is the key to both the performance of the minimisation and a solution of the deconvolution problem.
Preliminary numerical results with synthetic and real-world examples suggest that the method is capable of producing smooth, interpretable and improved reservoir response estimates. The computational time of the iterative method is significantly reduced compared to the direct method.

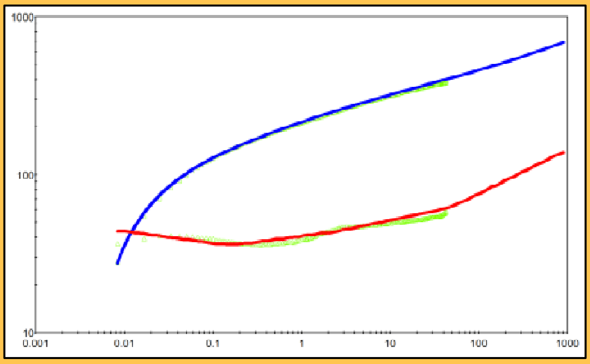

Fig.1: Improved pressure impulse (blue) and impulse derivative (red), with data (green)

"This internship provided me an excellent opportunity to discover a real-world inverse problem and to work in a great company with wonderful atmosphere. I have experienced the job which could be my career."

Lian Duan
OCCAM, University of Oxford

"It was a practical problem of importance to the company, it was challenging to Lian and it provided a model example that demonstrates the power of the Bayesian approach to inverse problems. The experience of software development in a commercial environment will be beneficial for Lian's future either as an academic researcher or as a software developer."

Chris Farmer, OCCAM, University of Oxford

Project Details

Partners
Paradigm
OCCAM, University of Oxford

Project investment
£10,000

Intern
Lian Duan

For further details on the technology:
Ralph Stadie
Paradigm
ralph.stadie@PDGM.com

For further information on internships and other collaborations:
Lorcán Mac Manus
Industrial Mathematics KTN
lbmm@industrialmaths.net
+44 (0) 1483 579108

This project was part of the programme of industrial mathematics internships managed by the Knowledge Transfer Network (KTN) for Industrial Mathematics. The KTN works to exploit mathematics as an engine for innovation. It is supported by the Technology Strategy Board, in its role as the UK's national innovation agency, and the Engineering and Physical Sciences Research Council, in its role as the main UK government agency for funding research and training in engineering and the physical sciences.

EPSRC
Engineering and Physical Sciences Research Council