Uncertainty Reduction in Reservoir Characterisation through Inverse Modelling of Dynamic Data: an Evolutionary Computation Approach

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Summary

Precise reservoir characterisation is the basis for reliable flow performance predictions and unequivocal decision making concerning field development. History matching is an indispensable phase of reservoir characterisation in which the flow performance history is integrated into the initially constructed reservoir model to reduce uncertainties. It is a computationally intensive nonlinear inverse problem and typically suffers from ill-posedness. Developing an efficient automatic history matching framework is the core goal of almost all studies on this subject.

To overcome some of the existing challenges in history matching, this thesis introduces new techniques which are mostly based on evolutionary computation concepts. In order to examine the techniques, in the beginning, the foundations of an automatic history matching framework are developed in which a reservoir simulator (ECLIPSE) is coupled with a programming language (MATLAB). Then, the introduced methods along with a number of conventional methods are installed on the framework, and they are compared with each other using different case studies.

Thus far, numerous optimisation algorithms have been studied for history matching problems to conduct the calibration step accurately and efficiently. In this thesis, the application of a recent-developed algorithm, artificial bee colony (ABC), is assessed, for the first time. It is compared with three conventional optimisers, Levenberg-Marquette, Genetic Algorithm, and Simulated Annealing, using a synthetic reservoir model. The comparison indicates that ABC can deliver better results and is not concerned with the landscape shape of problem. The most likely reason of its success is having a suitable balance between exploration and exploitation search capability. Of course, similar to all stochastic optimisers, its main drawbacks are computational expenses and being inefficient in high-dimensional problems.

Fitness approximation (proxy-modelling) approaches are common methods for reducing computational costs. All of the applied fitness approximation methods in history-matching problems use a similar approach called uncontrolled fitness approximation. It has been corroborated that the uncontrolled fitness approximation approach may mislead the optimisation direction. To prevent this issue, a new fitness approximation is developed in that a model management (evolution-control) technique is included. The results of the controlled (proposed) approach are compared with the results of conventional one using a case study (PUNQ-S3 model). It is shown that the computation can be reduced up to 75% by the proposed method. The proxy-modelling methods should be applied when the problem is not high-dimensional.

None of the current formats of the applied stochastic optimisers is capable of dealing with high-dimensional problems efficiently, and they should be applied in conjunction with a reparameterisation technique which causes modelling errors. On the other hand, gradient-based optimisers may be trapped into a local minimum, due to the nonlinearity of the problem. In this thesis, an inventive stochastic algorithm is developed for high-dimensional problems based on wavelet image-fusion and evolutionary algorithm concepts. The developed algorithm is compared with six algorithms (genetic algorithm with a pilot point reparameterisation, BFGS with a zonation reparameterisation, BFGS with a spectral decomposition reparameterisation, artificial bee colony, genetic algorithm and BFGS in full-parameterisation) using two different case studies. It is interesting that the best results are obtained by the introduced method.

Besides, it is well-known that achieving high-quality history matched models using any of the methods depends on the reliability of objective function formulation. The most widespread approach of formulation is Bayesian framework. Because of complexities in quantifying measurement, modelling and prior model reliability, the weighting factors in the objective function may have uncertainties. The influence of these uncertainties on the

outcome of history matching is studied in this thesis, and an approach is developed based on Pareto optimisation (multi-objective genetic algorithm) to deal with this issue. The approach is compared with a conventional (random selection) one. The results confirm that a high amount of computation can be saved by the Pareto approach.

In last part of this thesis, a new analytical simulator is developed using the transfer function approach. The developed method does not need the expensive history matching, and it can be used for occasions that a quick forecasting is sought and/or history matching of grid-based reservoir simulation is impractical. In the developed method, it is assumed a reservoir consists of a combination of TFs, and then the order and arrangement of TFs are chosen based on the physical conditions of the reservoir ascertained by examining several cases. The results reveal a good agreement with those obtained from the grid-based simulators.

An additional piece of work is done in this thesis in which the optimal infill drilling plane is estimated for a coal seam gas reservoir (semi-synthetic model constructed based on the Tiffany unit in the San Juan basin) by the use of the developed framework in which the objective function and the decision variables are set to be the net present value, and the location of infill wells, respectively.

Thesis declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution in my name and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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Mohammad Sayyafzadeh 3 July 2013

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List of publications

Journals:

- SAYYAFZADEH, M., POURAFSHARY, P., HAGHIGHI, M. & RASHIDI, F. 2011. Application of transfer functions to model water injection in hydrocarbon reservoir. Journal of Petroleum Science and Engineering, 78, 139-148.
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به نام خداوند جان و خرد

Dedicated to my mother, *Mahin Ghebti*, *who is* a constant source of support and encouragement, and to the memory of my father, *Abdolmajid Sayyafzadeh* who passed away just before I embarked on this journey.

تقدیم به

مادرم بلند تکیه گاهم، که دامان پر مهرش یگانه پناهم است و روح پاک پدرم که حاصل دستان خسته اش رمز موفقیتم شد.