ISAPP Symposium

7 and 8 November 2012

Venue:

Faculty of Civil Engineering and Geosciences
Delft University of Technology

Note on confidentiality

The ISAPP Symposium
is an internal meeting.

All case specific information, algorithms,
workflows and results presented
are confidential.

Wednesday 7 November 2012

9:00 - 9:30	*Registration and coffee/tea*		
9:30 - 9:45	**Richard Braal**	**TNO**	ISAPP overview
9:45 - 10:15	**Jan Dirk Jansen**	**TUD**	ISAPP technical overview
10:15 - 10:45	**Walter Renes**	**TNO**	Real-time monitoring and production optimization
10:45 - 11:15	*Coffee/tea break*		
11:15 - 11:45	**Martin Verlaan**	**Deltares**	New developments on data assimilation in geosciences
11:45 - 12:10	**Cristian Maris**	**TUD**	Distance-based, Feature Space Reparameterization in History Matching Using the EnKF
12:10 - 12:35	**Bogdan Sebacher**	**TUD**	Complex geology estimation using EnKF. A probabilistic approach
12:35 - 13:45	*Lunch*		
13:45 - 14:10	**Siavash Kahrobaei**	**TUD**	Adjoint-based history-matching of structural models using production and time-lapse seismic data
14:10 - 14:20	**Tudor Popa**	**TUD**	Ensemble methods for estimating the facies distribution in reservoir models
14:20 - 14:50	**Geir Evensen**	**Statoil**	Fast Model Update: A workflow for big-loop model updating
14:50 - 15:20	*Coffee/tea break*		
15:20 - 15:50	**Andreas Stordal**	**IRIS**	Overview of the research on ensemble-based inverse modeling
15:50 - 16:20	**Frank Wilschut**	**TNO**	Assisted history matching for SCAL experiments
16:20 - 16:50	**Gerard Joosten**	**Shell**	Model maturation
18:30	*Dinner*		

Thursday 8 November 2012

9:00 - 9:30	*Registration and coffee/tea*		
9:30 - 10:00	**Aris Twerda**	**TNO**	To ICD or not to ICD
10:00 - 10:25	**Koen Schutte**	**TUD**	Asphaltene deposition: a particle-laden flow problem
10:25 - 10:55	**Paul Egberts**	**TNO**	Waterflood optimization using an ensemble method - Application to a real field case
10:55 - 11:25	*Coffee/tea break*		
11:25 - 11:50	**Rahul Fonseca**	**TUD**	Improving the ensemble optimization method through covariance matrix adaptation (CMA-EnOpt)
11:50 - 12:00	**Eduardo de Barros**	**TUD**	Optimization of value of information in closed-loop reservoir management
12:00 - 12:25	**Bill Rossen**	**TUD**	Adjoint-Based Optimization of a Foam EOR Process
12:25 - 13:45	*Lunch*		
13:45 - 14:15	**Olwijn Leeuwenburgh**	**TNO**	Distance parameterization for efficient seismic history matching with the Ensemble Kalman filter
14:15 - 14:40	**Slawek Szklarz**	**TUD**	Efficient solution of the optimization problem in model-reduced gradient-based history matching
14:40 - 15:10	**Remus Hanea**	**TNO/TUD**	Bias estimation in reservoir engineering
15:10 - 15:30	*Coffee/tea break*		
15:30 - 16:00	**Antonio Corrêa**	**Petrobras**	Water Management Technology in Petrobras
16:00 - 16:30	**Bjarne Foss**	**NTNU/IO**	Shut-in optimization of shale-well systems
16:30 - 17:00	**Jan Dirk Jansen**	**TUD**	Two-level closed loop optimization
17:00	*Drinks*		

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Programme Wednesday 7 November

9:30 - 9:45 Richard Braal (TNO):
ISAPP overview

9:45 - 10:15 Jan Dirk Jansen (TU Delft):
ISAPP technical overview

10:15 - 10:45 Walter Renes, Ruud van der Linden (TNO):
Real-time monitoring and production optimization for upstream oil and gas

Production monitoring is the basis of production optimisation of oil and gas assets. Many assets nowadays have monitoring equipment and real-time data acquisition systems available that generate large amounts of real-time production data. This presentation will give an overview on real-time production monitoring and shows how real-time information and data management can be used to operate an asset. TNO project case histories will be shown that include real-time monitoring of wells, assets, early event detections, and preventing down time in wells.

10:45 - 11:15 ***Coffee/tea break***

11:15 - 11:45 Martin Verlaan, Julius Sumihar, Firmijn Zijl (Deltares):
New developments on data assimilation in geosciences

Data-assimilation is now applied in many different application domains in geosciences. Some of the developments are probably specific to one application, but many others may be relevant to other applications. In this talk, some developments in data-assimilation for meteorology, oceanography and hydrology will be discussed and illustrated with some examples for forecasting waves and storm-surges. The topics include observation sensitivity, iterative methods, dealing with sampling errors and non-linear behavior of the model.

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11:45 - 12:10 Cristian Maris (TU Delft), Jef Caers (Stanford University), Remus Hanea (TNO / TU Delft), Arnold Heemink, Jan Dirk Jansen (TU Delft):
Distance-based, Feature Space Reparameterization in History Matching Using the EnKF

As more and more emphasis is placed on accurately representing geological and structural uncertainty and variability in petroleum reservoir models, the goals of history matching techniques nowadays are extended beyond just accurately matching historical production data. In this regards, preserving the geological realism after the history matching procedure starts to become an issue of great significance. We propose to tackle this problem by considering an alternative, convenient representation and manipulation of this initial uncertainty which will lead to a different implementation of the Ensemble Kalman Filter (EnKF) algorithm. Thus, we use a distance-based ensemble representation of the uncertainty in a reservoir model, in order to map the problem into a so-called "feature space", and there, by using certain kernel function techniques in conjunction with the modified EnKF, we aim to better preserve and reconstruct certain realistic geological and structural features.

12:10 - 12:35 Bogdan Sebacher (TU Delft):
Complex geology estimation using EnKF. A probabilistic approach

In the past years, many applications of History Matching methods in general and Ensemble Kalman Filter in particular have been proposed, specially in order to estimate fields that provide uncertainty in the stochastic process defined by the dynamical system of hydrocarbons recovery. Such fields can be permeability fields or porosity fields, but as well can be the fields defined by the rock type (facies fields). In this paper we estimate, in the frame of EnKF process, the locations of the facies types that occur in the reservoir domain using a reparameterization of the facies field. We will introduce a new object named "probabilities field" through which we estimate the discrete fields defined by the facies types. We will test the model using a 2D reservoir which is connected with EnKF method as data assimilation technique.

12:35 - 13.45 *Lunch*

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13:45 - 14:10 Siavash Kahrobaei (TU Delft):
Adjoint-based history-matching of structural models using production and time-lapse seismic data

In spite of large uncertainties in the actual reservoir structure, the structural model is usually fixed during history-matching and only the flow properties of the model are allowed to vary. This often leads to unlikely or even unfeasible property updates and possibly to a poor predictive capability of the model. In those cases it may be expected that updating of the structural model will improve the quality of the history match. Preferably such structural updates should be implemented in the geological model, and not just in the dynamic model. In this paper we use a gradient-based history matching method to update the structural properties of the static model. We use an adjoint method to efficiently compute the derivatives of the data mismatch with respect to grid block porosities in the dynamic model and convert the corresponding volume changes to structural updates (layer thicknesses) in the static model. This method is suitable for structural updating of large scale reservoir models using production data and/or time-lapse seismics or other spatially distributed data. The method is tested on a realistically sized synthetic model, where time-lapse as well as production data have been used to update the structural model. We obtained significant improvement of the history match quality and demonstrated an increased predictive capability. In comparison to other data-assimilation techniques, the adjoint-based method does not suffer from inconsistencies between parameter and state vector updates and does not require localization of the updates. Adjoint-based history matching of structural models is computationally efficient. Moreover, since this method uses grid-block-by-grid-block sensitivities, it can be used to identify local areas with large inconsistencies in flow behavior which serve as an indicator for geological model updates.

14:10 - 14:20 Tudor Popa (TU Delft):
Ensemble methods for estimating the facies distribution in reservoir models

One of the main problems still associated with the use of data assimilation methods for history matching of reservoir models, is the lack of geological realism. The assumption is that reservoir models that are geologically realistic and match all available data, are better (i.e. give better predictions) than models that are not geologically realistic or do not match all data. In the normal work flow, the changes to the properties of reservoir models (like porosity and permeability) during the history-matching process are usually not consistent with geological knowledge about the reservoir and thus the optimal reservoir model is not obtained. Therefore, one should take into account these geological uncertainties, where structural uncertainties and facies distributions plays an important role in constraining the initial ensemble of possible geological realizations. The ensemble methods are used in order to condition these realizations on static and dynamic data. The two methods that will be used are the Ensemble Kalman Filter and the Ensemble Smother.

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14:20 - 14:50 Geir Evensen, Jan-Arild Skjervheim, Xavier van Lanen, Eli Zachariassen, Jon Sætrom (Statoil):
Fast Model Update: A workflow for big-loop model updating

To update a reservoir model with new information, e.g. obtained from seismic surveys or production data, is practically impossible to do on a regular basis because it requires a time-consuming rebuild of the model. Fast Model Update (FMU) provides a step change in the way we work with reservoir modeling.
In FMU the geological base model is built from bottom once, and thereafter new model realizations can be generated without manual intervention. In addition, the geological modeling software is connected to the reservoir simulator, which automatically simulates the different model realizations.
The automated workflow provides a repeatable and updatable modeling process that allows for fast screening of scenarios and where it is easy examine the impact of different input parameters. The fact that we can simultaneously generate and simulate multiple model realizations provides us with a mean to represent and propagate uncertainties through the whole modeling chain and to evaluate their impact on simulated profiles. Furthermore, when working with multiple realizations we can use statistical methods for conditioning the whole reservoir description on dynamical data. Thus, we have methods for automatically updating a geological model such that it is consistent with the observed production from wells and with 4D seismic.
In FMU we now work more integrated across disciplines because the reservoir modeling becomes a continuous process with updates of the whole model chain from geophysical interpretation to simulation, every time there is new information available. In addition we now work simultaneously with many possible model realizations rather than optimizing on a single "best model," and this to some extent requires a mind change by the users.
The value creation from FMU is connected to an improved and updated reservoir description, which facilitates better placement of wells and better planning of drainage strategies. An improved reservoir characterization will lead to IOR as well as accelerated recovery by better placement of wells and improved reservoir management.

14:50 - 15:20 ***Coffee/tea break***

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15:20 - 15:50 Andreas Stordal (IRIS): Overview of the research on ensemble-based inverse modeling

IRIS develops improved reservoir management methods. Better characterization of the reservoir, estimation of reservoir parameters by assimilation of production data, better simulation tools, production optimization and well control are current research areas. In particular we focus on fast updating of reservoir models with ensemble Kalman filter (EnKF) and other ensemble based methods. Lately this has evolved to include iterative filters, facies modelling, updating of models with complex geology, localization of the filter to avoid spurious correlations and development of the Adaptive Gaussian Mixture filter (AGM) and variants. We will show some examples of recently proposed methods.
IRIS has a long history of developing tools for production optimization and model updating in a closed-loop fashion. Our research started with well modeling and development of our in-house well simulator WEMOD in the 1990s and continued with focus on closed-loop reservoir management. Recently our research has evolved to include evaluation of a vast rage of optimization strategies, and zonal flowrate estimation.
IRIS is involved in the open source simulator development OPM (github.com/OPM) together with several research groups in Europe (SINTEF, Univ. of Bergen, Univ. of Stuttgart, Univ. Heidelberg, Statoil, Total, ++). The goal is to provide a suite of open source tools that can handle flow and transport of fluids in porous media. OPM aims to be useful for applications in different fields including petroleum, environmental engineering and CO2 sequestration.

15:50 - 16:20 Frank Wilschut (TNO): Assisted history matching for SCAL experiments

Flooding and centrifuge experiments are executed on core plugs in order to get estimates of two-phase relative permeability and capillary pressure as a function of the saturation of one of the phases. A reservoir simulator is used for history matching purposes to avoid the analytical assumptions traditionally used by analyzing SCAL (special core analysis) experiments.
A new history match approach has been developed to find a consistent set of relative permeability curves and capillary pressure curve. The new approach consists of a combination of two optimization algorithms: (1) Ensemble Randomized Maximum Likelihood Gradient (ENS) and (2) Perturbation Gradient (PG). Both have their particular advantages. The ENS algorithm is able to estimate the uncertainty of the relative permeability curves and capillary pressure curve. The PG algorithm will converge faster than the ENS algorithm.
This new approach is tested on a synthetic case and real case unsteady state experiments. In the synthetic case the history match procedure can find the "truth" permeability curves and capillary pressure curve by using the available observations. In the real cases the new history match approach can reproduce the observations and the results are comparable with previous history match experiments.

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16:20 - 16:50 Gerard Joosten (Shell):
Model maturation

History matching and future production optimisation in reservoir modelling is being done more and more with the help of automated or assisted computing techniques, such as design of experiments, Ensemble Kalman Filter or adjoint-based and other gradient-based or gradient-free techniques. With the advent of these efficient techniques, reservoir engineers also get less trivial applications of computer assisted optimisation at their disposal. In this presentation we will present such non-trivial application: model maturation.
We will demonstrate on field examples how an adjoint-based history match, updating gridblock properties, can highlight problematic areas of a model. The results show that good data matches, requiring unrealistic values for updated parameters, are not necessarily useless, but can actually provide a lot of information about unmodelled aspects of reservoir behaviour. Some of the learnings from such an exercise are of geological, others of operational nature.
Allowing reservoir model updates beyond what is considered to be in line with the (current) geological understanding of the reservoir, thus becomes a very useful multi-disciplinary tool to help steer thoughts on model improvement. This method, by now, has provided business-relevant insights in model behaviour for several assets around the globe.

18:30 ***Dinner***

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Programme Thursday 8 November

9:30 - 10:00 Aris Twerda (TNO):
To ICD or not to ICD

10:00 - 10:25 Koen Schutte (TU Delft):
Asphaltene deposition: a particle-laden flow problem

Asphaltene deposition is a major concern in crude oil production, as it causes obstructions in the flow path available to the oil and thereby diminishes the oil production rate. The focus of historical research has been on asphaltene chemistry and on the thermodynamics involved in the separation of asphaltenes from crude oil. Limited research has been conducted on the transport and agglomeration of asphaltenes after they have separated. However, this stage is crucial in the process of deposit formation.
In this presentation, we show why asphaltene deposition can be understood better when studied as a particle-laden flow problem. In order to arrive at a fundamental understanding of the physics involved, a meso-scale agglomeration and deposition model is currently under development: the basic principles will be explained and preliminary results will be shown. Also, an outlook will be given on how the insights obtained in this research can be used to arrive at optimized mitigation strategies and better engineering models for predicting asphaltene deposition.

10:25 - 10:55 Paul Egberts (TNO):
Waterflood optimization using an ensemble method - Application to a real field case

Numerical waterflood optimization is applied to two representative sector models of a real field case. Although the field is matured it is still under active development as there is still a large potential for oil production. A major challenge is to work out an injection and production strategy that optimizes the long term reservoir performance. As reservoir performance indicator the Net Present Value (NPV) was chosen, penalizing water injection and production. The operation of conventional wells was optimized and the resulting reservoir performance was compared to a reference case with a reactive control strategy. Furthermore the added value of smart wells was investigated by applying well completions with multiple ICVs of which the settings were optimized. The optimization problem was solved by a gradient based optimization algorithm. In the method applied in this study the gradient was approximated at each iteration by running a number of reservoir simulations each with a perturbed well control. Each of these simulations will have a slightly different NPV from which a sensitivity can be calculated using linear regression. It was found that the optimization of the two sector models with conventional wells resulted in a much more efficient sweeping as the optimized strategy reduced water injection and water production volumes significantly although the NPV increase can be small. The optimization with smart wells showed a further reduction of water injection and production volumes. The smart well optimization of one of the sector models showed in addition a significant increase of the NPV compared to the optimized conventional case. The method was able to discover injection and production strategies that improved sweep of the reservoir but are not easily found otherwise. The method also demonstrated its potential to support decisions on the number of ICVs per well and infill well placement.

10:55 - 11:25 ***Coffee/tea break***

11:25 - 11:50 Rahul Fonseca (TU Delft): Improving the Ensemble Optimization Method through Covariance Matrix Adaptation (CMA-EnOpt)

Ensemble Optimization(EnOpt) is a rapidly emerging method for reservoir model based production optimization. EnOpt uses an ensemble of controls, for a given reservoir model, to approximate the gradients of the objective functions with respect to the controls. Current implementations of EnOpt use a Gaussian ensemble with a constant standard deviation, i.e. a diagonal covariance matrix with entries that remain constant during the optimization process. The Covariance Matrix Adaptation Evolutionary Strategy (CMA-ES) is a derivative free optimization method, developed in the 'machine learning' community, which also uses an ensemble of controls but with a covariance matrix that is continually updated during the optimization process. It has shown to be an efficient method for several difficult optimization problems and has recently been applied in the petroleum industry for well location optimization. In this paper we investigate the scope to improve the computational efficiency of EnOpt through the use of covariance adaptation. We optimized water flooding of a multi-layer sector model containing multiple sealing and non-sealing faults. The controls used were inflow control valve settings at pre-defined time intervals for injectors and producers with undiscounted NPV as the objective function. We compared EnOpt and CMA-EnOpt starting from identical covariance matrices. We achieved a 35% reduction in the number of function evaluations using CMA-EnOpt compared to EnOpt. Moreover CMA-EnOpt achieved a higher objective function value.

11:50 - 12:00 Eduardo de Barros (TU Delft): Optimization of value of information in closed-loop reservoir management

Closed-loop control has been proposed as a concept for optimal reservoir management. In this approach, the life-cycle value of an asset is maximized by continuous updating of models and production strategies. In a typical closed-loop workflow, the production optimization step is executed separately from the history matching, which aims to obtain the best possible model description of the reservoir by incorporating information from measurements. In the climate sciences, it has been recognized that choosing where and when to obtain measurements could be crucial for improving the models, and thus the initial conditions for a subsequent forecast. This has led to the concept of optimal or targeted observations and so-called observing system sensitivity experiments. Also in reservoir management the benefits of measurements are recognized. The decision to obtain measurements is taken based on a cost-benefit analysis in which the value of information is quantified. This project will focus on possible approaches to incorporate these concepts in the closed-loop framework. Specific topics are: optimal measurement gathering strategies (measurement type, position, and timing) and optimal production strategies that maximize information about the reservoir. Both problems require a workflow that includes both production strategy and model updating.

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Programme Thursday 8 November

12:00 - 12:25 **Bill Rossen, Maryam Namdar Zanganeh (TU Delft), Hans Kraaijevanger, H. W. Buurman (Shell), Jan Dirk Jansen, and Bill Rossen (TU Delft):**
Adjoint-Based Optimization of a Foam EOR Process

We apply adjoint-based optimization to a Surfactant-Alternating-Gas foam process using a linear foam model introducing gradual changes in gas mobility and a nonlinear foam model giving abrupt changes in gas mobility as function of oil and water saturations and surfactant concentration.
For the linear foam model, the objective function is a relatively smooth function of the switching time. For the nonlinear foam model, the objective function exhibits many small-scale fluctuations. As a result, a gradient-based optimization routine could have difficulty finding the optimal switching time.
For the nonlinear foam model, extremely small time steps were required in the forward integration to converge to an accurate solution to the semi-discrete (discretized in space, continuous in time) problem. The semi-discrete solution still had strong oscillations in gridblock properties associated with the steep front moving through the reservoir. In addition, an extraordinarily tight tolerance was required in the backward integration to obtain accurate adjoints.
We believe the small-scale oscillations in the objective function result from the large oscillations in gridblock properties associated with the front moving through the reservoir. Other EOR processes, including surfactant EOR and near-miscible flooding, have similar sharp changes, and may present similar challenges to gradient-based optimization.

12:25 - 13:45 ***Lunch***

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13:45 - 14:15 Olwijn Leeuwenburgh (TNO):
Distance parameterization for efficient seismic history matching with the Ensemble Kalman filter

The Ensemble Kalman Filter (EnKF), in combination with travel-time parameterization, provides a robust and flexible method for quantitative multi-model history matching to time-lapse seismic data. A disadvantage of the parameterization in terms of travel-times is that it requires simulation of models beyond the update time. A new distance parameterization is proposed for fronts, or more generally, for isolines of arbitrary seismic attributes, that circumvents the necessity of additional simulation time. An accurate Fast Marching Method for solution of the Eikonal equation in Cartesian grids is used to calculate distances between observed and simulated fronts which are subsequently used as innovations in the EnKF.
Experiments are presented that demonstrate the functioning of the method in synthetic 1D and 2D cases that include uncertain model properties, and merging or multiple secondary fronts. Results are compared with those resulting from direct use of saturation data. The proposed algorithm significantly reduces the number of data while still capturing the essential information, it removes the need for seismic inversion when the oil-water front is identified only, and it produces a more favorable distribution of simulated data, leading to improved functioning of the EnKF.

14:15 - 14:40 Slawek Szklarz (TU Delft):
Efficient solution of the optimization problem in model-reduced gradient-based history matching

Adjusting parameters in reservoir models by minimizing the discrepancy between the model's predictions and actual measurements is a popular approach known as history matching. One of the most effective techniques is gradient-based history matching. For reservoir models, the number of grid blocks and therefore, the size of the problem can become very large. In recent years, model-order reduction techniques aiming to replace large, complex dynamic systems with lower-dimension models have been incorporated into history matching. In both gradient-based history matching and model-reduced gradient-based history matching, rst-order optimization methods are used in order to minimize the mismatch between simulated well-production data and observed production. In this work, we investigate the performance of some optimization methods on the minimization problem in model-reduced gradient-based history matching. The methods were tested on the history matching
of a small reservoir model with synthetic measurements. Our results show that fast first-order techniques such as the spectral projected gradient method can compete with the popular quasi-Newton BFGS approach.

14:40 - 15:10 Remus Hanea (TNO/TU Delft):
Bias estimation in reservoir engineering

15:10 - 15:30 ***Coffee/tea break***

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Programme Thursday 8 November

15:30 - 16:00 Antonio Correa (Petrobas):
Water management technology in Petrobas

16:00 - 16:30 Bjarne Foss (NTNU/IO):
Shut-in optimization of shale-well systems

This talk presents a novel operational scheme for enhanced utilization of late-life shale multi-well systems. These systems are characterized by a large number of geographically spread wells and pads, where a substantial number of the wells are producing low erratic rates due to reservoir pressure depletion and well liquid loading. By applying a cyclic shut-in and production strategy, the scheme avoids well liquid loading and optimizes the production from a set of late-life wells at a shared production pad.
The scheduling of well shut-ins is based on mixed integer formulations derived from a generalized disjunctive program (GDP) describing the logics of the well shut-ins and related constraints on the switching times. The optimization of the shale-gas production is performed on a novel single well and reservoir proxy model, which despite its simplicity, is shown to capture essential high frequency dynamics of late-life shale wells. The GDP formulation lends itself both to a complete MILP reformulation and reduced size MINLP reformulations, where a computational study indicates in favor of the MILP formulation. We include numerical examples to demonstrate the potential benefit of applying the proposed cyclic scheme compared to a non-optimized approach.
At the end of the talk some other IO center research projects will briefly be mentioned.

16:30 - 17:00 Jan Dirk Jansen (TU Delft):
Two-level closed loop optimization

17:00 ***Drinks***