Technical Program for Thursday May 31, 2012

ThPl1 EL5

Invited Industry Presentations (Plenary Session)

08:40-09:25 ThPl1.2

*The Role of Automation in Future Offshore Operations**

Hersvik, Karl Johnny — Statoil ASA

09:25-10:10 ThPl1.3

*All Subsea Solutions, Technology to Move the Platform to the Seabed**

Johansen, Christina — FMC Kongsberg Subsea AS

ThA1 EL5

Reservoir Optimization (Regular Session)

10:30-10:50 ThA1.1

Estimation of Optimal Well Controls Using the Augmented Lagrangian Function with Approximate Derivatives, pp. 1-6

Do, Sy — Univ. of Tulsa

Forouzanfar, Fahim — Univ. of Tulsa

Reynolds, Albert — Univ. of Tulsa

When efficient adjoint code for computing the necessary gradients is available, the augmented Lagrangian algorithm provides an efficient and robust method for constrained optimization. Here, we develop an augmented Lagrangian algorithm for constrained optimization problems where adjoint code is not available, and the number of optimization variables is so large that the approximation of gradients with the finite-difference method is not computationally feasible. Our procedure applies a preconditioned steepest ascent algorithm to maximize an augmented Lagrangian function which directly incorporates all bound constraints as well as all inequality and equality constraints. The preconditioned gradient of the augmented Lagrangian is estimated directly using a simultaneous perturbation stochastic approximation (SPSA) with Gaussian perturbations where the preconditioning matrix is a covariance matrix selected to impose a degree of temporal smoothness on the optimization variables, which, for the specific application considered here, are the well controls. Our implementation of this augmented Lagrangian method is applied to estimate the well controls which maximize the net present value (NPV) of production for the remaining life of a given oil reservoir.

10:50-11:10 ThA1.2

Real-Time Production Optimization and Reservoir Management at the IO Center, pp. 7-12

Foss, Bjarne — Norwegian Univ. of Science & Tech.

This paper presents research results within real-time production optimization and reservoir management at the Center for Integrated Operations in the Petroleum Industry (IO center). This includes life-cycle and long term issues like well location and target production rates. Further, results on short term production optimization, for instance the allocation of target production between wells and routing of wells into pipelines, will be presented. Finally, results on value chain optimization, where the production chain from reservoir to export is modelled, are reviewed.

11:10-11:30 ThA1.3

The Optimization Problem in Model-Reduced Gradient-Based History Matching, pp. 13-18

Szklarz, Slawomir — Delft Univ. of Tech.

Rojas, Marielba — Delft Univ. of Tech.

Kaleta, Malgorzata — Shell Global Solutions International

We present preliminary results of a performance evaluation study of several gradient-based state-of-the-art optimization methods for solving the nonlinear minimization problem arising in model-reduced gradient-based history matching. The issues discussed also apply to other areas, such as production optimization in closed-loop reservoir management.

11:30-11:50 ThA1.4

Integrated Capacitance-Resistance Model for Characterizing Waterflooded Reservoirs, pp. 19-24

Kim, Jong Suk — Univ. of Texas at Austin

Lake, Larry W. — Univ. of Texas

Edgar, Thomas F. — Univ. of Texas at Austin

Capacitance-resistance modeling of petroleum reservoirs has been used successfully to analyze transient behavior of petroleum reservoirs both onshore and offshore. This paper presents a linear reservoir model that provides advantages over the nonlinear capacitance-resistance model: convex objective function, efficient solution, and direct estimation of confidence limits on model parameters. The proposed procedure uses a constrained linear multivariate regression to infer preferential permeability trends and fractures in a waterflooded reservoir. The relationship between interwell-connectivities and interwell-distance between injector-producer well-pairs was also investigated.

11:50-12:10 ThA1.5

Control Performance Monitoring of Excessive Oscillations of an Offshore Production Facility, pp. 25-32

Zheng, Yingying — Univ. of Southern California

Qin, S. Joe — Univ. of Southern California

Barham, Michael — Chevron

In remote operation of offshore platforms, real time control systems must be well maintained for efficient and safe operations. Early detection of control and equipment performance degradation is critical and is the foundation for implementing higher level integrated optimization. Poor control performance is usually the result of undetected deterioration in control valves, inadequate performance monitoring, and poor tuning in the controllers. In this work, data-driven approaches to monitoring control performance are applied to an offshore platform. The minimum variance control benchmark for single loops and the covariance benchmark for multi-loops are used to detect deteriorated control variables. The covariance benchmark is used to determine the directions with significantly worse performance versus the benchmark. To detect valve stiction, the Savitzky-Golay smoothing filter is combined with a curve fitting method. The Savitzky-Golay filter has the advantage of preserving features of the distribution such as relative maxima, minima and widths. A stiction index is used to indicate whether a valve stiction occurred. The OSIsoft PI system is suggested as the implementation platform. Real-time data can be exchanged between PI and MATLAB via OPC interface.

ThA2 EL6

Robotics and Autonomous Systems (Regular Session)

10:30-10:50 ThA2.1

RoboGasInspector – a Mobile Robotic System for Remote Leak Sensing and Localization in Large Industrial Environments: Overview and First Results, pp. 33-38

Soldan, Samuel — Univ. of Kassel

Bonow, Gero — Univ. of Kassel

Kroll, Andreas — Univ. of Kassel

In order to automate the routine inspections in large industrial environments a mobile robotic system is being developed in the project RoboGasInspector. The robot's sensor-head consists of

different instruments for remote sensing using multiple measurement principles. First results show that passive IR-thermographic imaging can be used to detect leaks in pipes as well as liquid spills on the ground. The measurable effects are the temperature profile disturbance due to expansion of pressured gas and evaporative cooling, respectively. Tunable Diode Laser Absorption Spectroscopy (TDLAS) measurement systems provide for quantitative gas concentration measurements and feature a high sensitivity due to the active measurement principle. On the contrary, TDLAS systems measure just the concentration along a path at a time and require a diffusely reflecting background. Using a Pan-Tilt Unit, objects/areas can be scanned and abnormal gas concentrations can be identified. This contribution introduces the project RoboGasInspector and presents the used measurement technology as well as first results.

10:50-11:10 ThA2.2

A Learning Camera Platform for Remote Operations with Industrial Manipulators, pp. 39-46

Fjerdingen, Sigurd Aksnes	SINTEF ICT
Bjerkeng, Magnus	NTNU
Transeth, Aksel Andreas	SINTEF ICT
Kyrkjebø, Erik	Norwegian Univ. of Science and Tech.
Røyrøy, Anders	Statoil ASA

Robot manipulators may be used as flexible camera platforms by mounting cameras on the wrist of the robot. In this paper we present a new way of interaction between an operator and the camera platform, where the operator wants to get a visual overview of a remote operation. The goal is to relieve the operator from controlling both the operation and the camera platform simultaneously, and allow the operator to focus only on the operation while the camera plaform is automatically controlled based on learned operator preferences. We describe an architecture for learning from operator inputs, and use an active camera control algorithm as a base for learning. An M-RAN sequential function approximator is used as memory function. Experimental results on a demonstration case indicate that the camera platform responds to and remembers differences in operator preference.

11:10-11:30 ThA2.3

A Step-Wise Approach to Oil and Gas Robotics, pp. 47-52

Anisi, David A.	ABB
Skourup, Charlotte	ABB

Developing a reliable and intelligent robotic system which enables the remote operation of normally unmanned oil and gas facilities requires innovative and novel technical solutions. Our strategy for meeting these challenges is based on a step-wise approach involving development and validation of the technology in increasingly demanding settings. This starts with proof-of-concept demonstrations in our indoor test facility located in Oslo, Norway. Taking this one step further, robots and applications are further developed, tested and validated in a co-located outdoor test facility. This is normally an intermediate step before bringing demonstrators onto real oil and gas facilities. In this paper, this design philosophy is elaborated upon and illustrated using the development of a valve manipulation application as an example.

11:30-11:50 ThA2.4

CAD-Based Training of an Expert System and a Hidden Markov Model for Obstacle Detection in an Industrial Robot Environment, pp. 53-58

Kaldestad, Knut Berg	Univ. of Agder
Hovland, Geir	Univ. of Agder
Anisi, David A.	ABB

Deploying industrial robots in harsh outdoor environments require additional functionalities not currently provided. For instance, movement of standard industrial robots are pre-programmed to avoid collision. In dynamic and less structured environments, however, the need for online detection and avoidance of unmodelled objects arises. This paper focus on online obstacle detection using a laser sensor by proposing three dierent approaches, namely a CAD-based Expert System (ES) and two probabilistic methods based on a Hidden Markov Model (HMM) which requires observation based training. In addition, this paper contributes by providing a comparison between the CAD-based ES and the two versions of the HMM, one trained with real sensor data, and one where virtual sensor data has been extracted from the CAD-model and used during the training phase.

11:50-12:10 ThA2.5

Remote Calibration and Trajectory Replanning for Robot Manipulators Operating in Unstructured Environments, pp. 59-65

Leite, Antonio C.	Federal Univ. of Rio de Janeiro
Lizarralde, Fernando	Federal Univ. of Rio de Janeiro
From, Pål Johan	Norwegian Univ. of Life Sciences
Costa, Ramon R.	COPPE - Federal Univ. of Rio de Janeiro
Hsu, Liu	COPPE - Federal Univ. of Rio de Janeiro

In this work the problem of remote calibration and trajectory replanning for a subsea robotic manipulator is considered. Because the trajectory planning is normally done in a structured environment, several uncertainties arise when the robot is placed on the seabed and these need to be compensated for to guarantee that the task specifications are fulfilled. We address the particular problem of configuration errors in the robot base with respect to the configuration used during the off-line trajectory planning. A calibration method based on both internal and external sensors is presented in order to estimate the uncertainty in the location of the robot. Moreover, a trajectory replanning strategy in the Cartesian velocity space is proposed to guarantee that the originally planned trajectory is followed. Simulation and experiments performed with a 6-DoF robot manipulator and a real calibration grid show the viability of the proposed planning and control schemes.

ThB1 EL5

Directional Drilling (Regular Session)

13:30-13:50 ThB1.1

Rotary Steerable Directional Drilling Stick/Slip Mitigation Control, pp. 66-71

Bayliss, Martin Thomas	Schlumberger ltd
Panchal, Neilkunal	Cranfield Univ.
Whidborne, James F.	Cranfield Univ.

This paper details the online-identification-based adaptive design of a stick/slip minimization algorithm and top-drive servo control for Rotary Steerable System (RSS) directional drilling tools. Stick/slip in this context refers to the downhole angular velocity variation of the bit about a nominal value. The basic pole placement controller designs are SISO linear but recursively evaluated based on an online Recursive Least Squares (RLS) identification of the open-loop plant parameters. System architecture implications for the stated algorithm are discussed, and simulation results included with and without adaptive stick/slip mitigation.

13:50-14:10 ThB1.2

L1 Adaptive Control for Directional Drilling Systems, pp. 72-77

Sun, Hui	Univ. of Illinois at Urbana-Champaign
Li, Zhiyuan	UIUC
Hovakimyan, Naira	UIUC
Basar, Tamer	Univ. of Illinois at Urbana-Champaign
Downton, Geoff	Schlumberger

This paper considers downhole directional drilling systems in the presence of unexpected variations in steering force, input delays, measurement noise and measurement delays and explores

application of L1 adaptive controller for the trajectory control problem. The Explicit Force, Finitely Sharp, Zero Mass (EFFSZM) model is used for the steering system, in which spatial delays, modeling inaccuracies, parametric uncertainties, and noise are considered. The L1 adaptive controller ensures that the centerline of the borehole follows a well path planned according to apriori available geologic conditions and local residential information. Path tracking results are demonstrated by simulations.

14:10-14:30 ThB1.3

Vector Based Kinematic Closed-Loop Attitude Control-System for Directional Drilling, pp. 78-83

Panchal, Neilkunal — Cranfield Univ.
Bayliss, Martin Thomas — Schlumberger ltd
Whidborne, James F. — Cranfield Univ.

An attitude control system is presented here, where the attitude of a drilling tool is represented by a unit vector and hence non-linearities of Euler angles are avoided. It is shown in simulation that the control system has a stable orbit about the desired attitude in the presence of drop and turn rate biases, and with a spatial delay due to the sensors. The attitude controller is embedded into a way-point tracking control system where it is demonstrated that the controller tracks the position and attitude of each way-point and minimizes the strain energy along the path.

14:30-14:50 ThB1.4

A Hybrid Approach to Closed-Loop Directional Drilling Control Using Rotary Steerable Systems, pp. 84-89

Matheus, Justo — Schlumberger
Ignova, Maja — Schlumberger
Hornblower, Peter John — Schlumberger

This paper proposes the use of a hybrid approach to perform the trajectory control in the oil drilling industry using Rotary Steerable Systems (RSS). Two levels of automation are proposed, the attitude control (Level 1) regulating inclination and azimuth downhole and the outer loop (Level 2), that monitors the performance of the inner loop and controls the directional drilling commands issued to the tool in order to follow a pre-defined plan. The attitude controller was developed using various simulation techniques including Hardware in the Loop, which implements the dynamical model of the regulated variables downhole. This approach guarantees the reliability of the embedded software implemented in the RSS tool.

14:50-15:10 ThB1.5

An Adaptive PID Switching Controller for Pressure Regulation in Drilling, pp. 90-94

Siahaan, Hardy B. — International Res. Inst. of Stavanger (IRIS)
Jin, Huiyu — Univ. of Science and Tech. of China
Safonov, Michael G. — Univ. of Southern California

Managing well pressure in petroleum drilling is essential for avoiding instability. An adaptive PID control using the unfalsified procedure is proposed to regulate the pressure. The scheme chooses the right PID parameter from a set of candidate parameters based on the data measurement instead of any hypothetical model. The scheme eliminates the difficulties in tuning the PID even without any prior knowledge of the system to regulate and results in fast controller adaptation.

ThB2 EL6

Slugging and Gas Lift (Regular Session)

13:30-13:50 ThB2.1

Stabilizing Gas-Lift Well Dynamics with Free Operating Point, pp. 95-100

Plucenio, Agustinho — Univ. Federal de Santa Catarina
Ganzaroli, Cleber A. — Federal Univ. of Santa Catarina
Pagano, Daniel Juan — Federal Univ. of Santa Catarina

Gas lift is one of the most used artificial lift methods worldwide. In Brazil it responds for more than 70% of the total oil production. Gas lift wells are known to present oscillatory production behavior associated with phenomena like heading and density wave. This work presents an innovative way to control these oscillations. The approach adopted controls the well dynamics without fixing any set point, decoupling the dynamic control from the optimization algorithm.

13:50-14:10 ThB2.2

Controllability Analysis of Severe Slugging in Well-Pipeline-Riser Systems, pp. 101-108

Jahanshahi, Esmaeil — Norwegian Univ. of Science and Tech.
Skogestad, Sigurd — Norwegian Univ. of Science & Tech.
Hoel Helgesen, Anette — BP Norge AS

Active control of the production choke valve is the recommended solution to prevent severe slugging flow conditions at offshore oilfields. The focus of this work is to find the structure of a simple, yet robust anti-slug control system. In order to find suitable control variables for stabilization, a controllability analysis of the system with different available measurements or different combinations of them was performed. Moreover, for including robustness and performance requirements at the same time, the controllability analysis was extended to a mixed sensitivity H-infinity optimization problem. Two case studies were considered; first, the controllability analysis was performed on a pipeline-rise system using a 4-state model for comparing the results to the previous works. Next, using a 6-state model, the results were extended to a more general well-pipeline-riser system. The controllability results were in accordance with the practical experience in anti-slug control.

14:10-14:30 ThB2.3

Model-Based Control of Slugging: Advances and Challenges, pp. 109-115

Di Meglio, Florent — UCSD
Kaasa, Glenn-Ole — Statoil, Res. Centre Porsgrunn
Petit, Nicolas — MINES ParisTech
Alstad, Vidar — Norsk Hydro ASA

We review recent advances in the suppression of the slugging phenomenon by model-based control. We focus on three aspects of recent contributions: models, observers and control laws. For each category, we evaluate and compare existing solutions, and propose directions for improvement.

14:30-14:50 ThB2.4

Gas Injection for Hydrodynamic Slug Control, pp. 116-121

Krima, Hazem — Cranfield Univ.
Cao, Yi — Cranfield Univ.
Lao, Liyun — Cranfield Univ.

Gas injection as an effective method to mitigate hydrodynamic slug has been studied using OLGA simulation. Different control strategies have been investigated to reduce the amount of injected gas required to mitigate slugs. The control strategies are based on using a PI controller to control the valve opening of gas injection through various riser measurements used as controlled variables. The results show that the holdup transmitter at the riser top as the controlled variable is the best control strategy, followed by the differential pressure across the riser. It is also concluded that using riser top choking reduces the requirement of injection gas.

14:50-15:10 ThB2.5

A New Discrete Slug-Flow Controller for Production Pipeline Risers, pp. 122-127

Enricone Stasiak, Marina — Federal Univ. of Santa Catarina
Pagano, Daniel Juan — Federal Univ. of Santa Catarina
Plucenio, Agustinho — Univ. Federal de Santa Catarina

In this paper we propose a new discrete slug-flow control to

stabilize severe slugging oscillations in submarine oil-risers. Since the practical objetive is to stabilize the flow keeping the surface choke with a minimum pressure drop, the idea of pressure set-point looses significance. One could say that the control problem is well solved if the pressures and flow-rates do not oscillate while the surface choke is kept opened well above the opening which characterizes the beginning of the limit cycle. The idea is to develop a control strategy which supres the oscillation while keeping the choke opening operating around a desired opening value. If the oscillations are suppressed the resultant pressures will be a consequence of the input mass flow-rate, fluid characteristics and the system geometry. Simulation results were obtained for a case study using a comercial software in order to validate the proposed control system.

ThC1 EL5

Drilling and Oil Field Development (Regular Session)

15:30-15:50 ThC1.1

Bottomhole Pressure Estimation and L1 Adaptive Control in Managed Pressure Drilling System, pp. 128-133

Li, Zhiyuan UIUC

Hovakimyan, Naira UIUC

Kaasa, Glenn-Ole Statoil, Res. Centre Porsgrunn

This paper designs an integrated estimator and L1 adaptive control scheme to address the two main challenges involved in the Managed Pressure Drilling (MPD) system: first, the bottomhole states are updated at a low rate, which can be viewed as unmeasured and thus need to be estimated in real time; and second, the drilling process is subject to uncertainties including unknown parameters (e.g., frictions, densities), unmodeled actuator dynamics and noise, which requires a robust adaptive controller for the control of the bottomhole pressure. The estimator provides fast estimation of the bottomhole pressure and flow rate, based on the available measurements from the top-side. The L1 adaptive controller drives the bottomhole pressure to the desired value following a reference model. We also provide a solution to handle input delay. The design is based on a recently developed nonlinear drilling model. The results demonstrate that the L1 adaptive controller has guaranteed performance bounds for both the input and the output signals of the system while using the estimation of the regulated outputs. Simulations that include different operational conditions verify the theoretical findings.

15:50-16:10 ThC1.2

Experimental Control of Annulus Pressure While Drilling Oil Wells, pp. 134-139

Vega, Marcia UFRRJ

Freitas, Marcela UFFRJ

Folsta, Mauricio PETROBRAS

Gandelman, Roni PETROBRAS

Martins, Andre PETROBRAS

Under a conventional oil well drilling task, the pore pressure (minimum limit) and the fracture pressure (maximum limit) define mud density range and pressure operational window. During oil well drilling, several disturbances affect bottom hole pressure; for example, as the length of the well increases, the annulus bottom hole pressure varies for growing hydrostatic pressure levels. In addition, the pipe connection procedure produces disturbances in well fluids flow, changing well pressure. The objective being tracked is operating under desired pressure levels, which assures process safety, also reducing costs, as drilling operation demands around U$500,000.00/day. In this scenario, control techniques are important tools for narrow operational windows, commonly observed at deepwater and pre-salt layer environments. The major objective of this paper is controlling annulus bottom hole pressure of a drilling experimental unit, using the choke opening index as the manipulated variable, in order to guarantee safe operation (target annulus bottom hole pressure), despite the inherent process disturbances and under a scenario that maximization of ROP (rate of penetration) is a target.

16:10-16:30 ThC1.3

Prospective Approaches to Field Model Adjustment Over Oil Production Process, pp. 140-144

Grigoriev, Leonid Russian State Univ. of Oil and Gas

Kazakov, Nikolay Russian State Univ. of Oil and Gas

When designing automated management systems for oilfield development one of the main problems is the uncertainty of control object stemming from natural factors. Field properties' identification becomes a key task here. Field model adjustment plays a crucial role in this process. It is clear that history matching, as well as control, should be conducted on different time scales. Under the close-loop management, real-time adjustment (history matching) is used, but long-term management requires the model to be adjusted over the entire production lifecycle. This problem can be solved with the help of synergetic models. This article explains why and how the synergistic approach can be applied to the problem of field development management and describes some prospective approaches to field model adjustment throughout the life cycle.

16:30-16:50 ThC1.4

A Moving Horizon Observer for Estimation of Bottomhole Pressure During Drilling, pp. 145-150

Sui, Dan The Norwegian Univ. of Science and Tech.

Nybø, Roar SINTEF Petroleum Res.

Hovland, Svein Statoil

Johansen, Tor Arne Norwegian Univ. of Science and Tech.

To ensure safe and stable drilling operation, bottomhole pressure(BHP) should be kept within some region. However measurement of the BHP is sometimes not available or reliable, especially when the circulation is low, e.g., during pipe connection procedures. This paper presents the application of a moving horizon estimation (MHE) method for online estimation of the BHP during petroleum drilling. In the proposed MHE formulation the states are estimated by a forward simulation with a pre-estimating observer. Moreover, it considers the constraints of states/outputs in the MHE problem. Application of the observer to a real data set from a North Sea oil well illustrates potential benefits.

16:50-17:10 ThC1.5

Parallel Computing in Optimal Design of Development of Multilayer Oil and Gas Fields, pp. 151-156

Akhmetzyanov, Atlas Inst. of Control Sciences, Russian Acad. of Sciences

Ermolaev, Alexander Gubkin Russian State Univ. of Oil and Gas

Grebennik, Oleg Inst. of Control Sciences of Russian Acad. of Sciences

In this paper we consider problems of optimization and selection of development systems (technologies) of oil/gas fields, consisting of some disjoint oil/gas pools (in terms of hydrodynamics), tied by resource constraints or general oil/gas production plan. In order to solve these problems, formulated as MILP models, we have developed approximate algorithm using Lagrangian relaxation. Initially we consider the problem for oil fields and then for gas fields. Contrary to another models and techniques, used for solving the similar problems, our models and algorithms allow us to coordinate allocation of production volumes and reserves among the pools with selection of optimal development system, as well as optimization of technological parameters for each pool. We have also examined the perspective approaches, using both multilevel decomposition of oil reservoirs, and hierarchical splitting, and parallel computing on supercomputer for developing effective problem-solving procedures.

ThC2 EL6

Methods (Regular Session)

15:30-15:50 ThC2.1

Designing Large-Scale Balanced-Complexity Models for Online Use, pp. 157-162

Elgsæter, Steinar M. Cybernetica AS

Kittilsen, Pål Cybernetica AS

Hauger, Svein Olav Cybernetica AS

Model-based online applications such as soft-sensing, fault detection or model predictive control require representative online models. Basing models on physics has the advantage of naturally describing nonlinear processes and potentially describing a wide range of operating conditions. Implementing adaptivity is essential for online use to avoid model performance degradation over time and to compensate for model imperfection. Requirements for identifiability and observability, numerical robustness and computational speed place an upper limit on model complexity. These considerations motivate the design of balanced-complexity physical models with adaptivity for online use. Techniques used in the design of balanced complexity models are given with examples from oshore oil and gas production. Despite potential benefits, the effort required to implement balanced-complexity models,particularly at large scales, may deter their use. This paper presents a Modelica-based approach to reduce implementation effort by interfacing exported Modelica models with application code by means of a generic interface. The suggested approach is demonstrated by parameter estimation for a subsea well-manifold-pipeline system.

15:50-16:10 ThC2.2

Ensemble Kalman Filter Predictor Bias Correction Method for Non-Gaussian Geological Facies Detection, pp. 163-170

Trivedi, Japan Univ. of Alberta, Civil and Environmental Engineering

Nejadi, Siavash Univ. of Alberta, Civil and Environmental Engineering

Leung, Juliana Univ. of Alberta, Civil and Environmental Engineering

The Ensemble Kalman Filter (EnKF) is a Monte-Carlo based technique for assisted history matching and real time updating of reservoir models. However, it often fails to detect facies boundaries and proportions as the facies distributions are non-Gaussian, while geologic data for reservoir modeling is usually insufficient. It is convenient to represent distinct facies with non-Gaussian categorical indicators; we implemented discrete cosine transform (DCT) to parameterize the facies indicators into coefficients of the retained cosine basis functions that are Gaussian. For highly complex and heterogeneous models, though observed data were matched, it failed to reproduce realistic facies distribution corresponding to reference variogram and facies proportion. In this paper we propose a new ensemble filtering method in-between of EnKF and PF, where EnKF as predictor combines the advantages of accurate large updates with small ensembles and corrector for non-Gaussian distributions followed by EnKF again for analysis step. Correction is performed by regenerating new realizations using a new pilot point method. The ensemble members that are more consistent with the early production history and the available geological information are considered as high weight particles and used for the applications. Combination of DCT-EnKF and regenerating new realizations using the new pilot point method demonstrates reasonable improvement and reduction of uncertainty in facies detection. Incorporating the new step in the procedure assists the filter to honor the reference distribution and experimental variogram during the history matching process and presents an important potential in improved characterization of complex reservoirs.

16:10-16:30 ThC2.3

Discrete Time Variable Structure Control for the Dynamic Positioning of an Offshore Supply Vessel, pp. 171-176

Benetazzo, Flavia Univ. Pol. delle Marche

Ippoliti, Gianluca Univ. Pol. delle Marche

Longhi, Sauro Univ. Pol. delle Marche

Raspa, Paolo Univ. Pol. delle Marche

This paper presents a Discrete-Time Variable-Structure Control (DTVSC) for the dynamic positioning system of a marine supply vessel. The DTVSC guarantees robustness with respect to disturbances and parametric variations. Two wave-filtering approaches are employed: the Extended Kalman filter (EKF) and the multi-rate Kalman filter (MREKF) . The proposed solution is compared with a PID-based control and a passive non-linear wave filter. The reported simulations show that the proposed solution produces better performances and it is robust in the presence of input disturbances and model uncertainties.

16:30-16:50 ThC2.4

Robust Dynamic Positioning of Offshore Vessels Using Mixed-μ Synthesis, Part I: A Control System Design Methodology, pp. 177-182

Hassani, Vahid Inst. Superior Tecnico (IST)

Soerensen, Asgeir Norwegian Univ. of Science and Tech.

Pascoal, Antonio M. ISR-Inst. Superior Tecnico

This paper describes a procedure to design robust controllers for Dynamic Positioning (DP) of ships and offshore rigs subjected to the influence of sea waves, currents, and wind loads using H∞ and mixed-μ techniques. To this effect, practical assumptions are exploited in order to obtain a linear design model with parametric uncertainties describing the dynamics of the vessel. Appropriate frequency weighting functions are selected to capture the required performance specifications at the controller design phase. The proposed model and weighting functions are then used to design robust controllers. The problem of wave filtering is also addressed during the process of modeling and controller design. The key contribution of the paper is twofold: i) it affords system designers a new method to efficiently obtain linearized design models that fit naturally in the framework of H∞ control theory, and ii) it describes, in a systematic manner, the different steps involved in the controller design process. Part II in a companion paper contains the details of simulations and results of experimental model tests in a towing tank equipped with a hydraulic wave maker.

16:50-17:10 ThC2.5

Robust Dynamic Positioning of Offshore Vessels Using Mixed-μ Synthesis Part II: Simulation and Experimental Results, pp. 183-188

Hassani, Vahid Inst. Superior Tecnico (IST)

Soerensen, Asgeir Norwegian Univ. of Science and Tech.

Pascoal, Antonio M. ISR-Inst. Superior Tecnico

This paper is a follow-up of a companion paper by Hassani et al. (2012b) on a control design methodology for Dynamic Positioning (DP) of marine vessels and offshore rigs subjected to the influence of sea waves, currents, and wind loads using mixed-μ synthesis. The present paper describes the results of a design exercise in which robust controllers were designed for a representative vessel. Its main focus is on the discussion of the results of numerical simulations and experimental model-testing of a set of robust DP controllers operating under different sea conditions: calm, moderate, high, and extreme seas. The robust DP controllers were first evaluated in a high fidelity nonlinear DP simulator, illustrating the efficiency of the design. To bridge the gap between theory and practice, the results were experimentally verified by model testing of a DP operated ship, the Cybership III, under different simulated sea conditions in a towing tank equipped with a hydraulic wave maker.

FrPlT3 EL5

Invited Keynote Presentations (Plenary Session)

08:30-09:15 FrPlT3.1

Recent Developments in Model-Based Optimization and Control of Subsurface Flow in Oil Reservoirs, pp. 189-200

Van den Hof, Paul M.J. Eindhoven Univ. of Tech.
Jansen, Jan Dirk Delft Univ. of Tech.
Heemink, Arnold Delft Univ. of Tech.

The past ten years have seen an increasing application of systems and control theory to porous media flow. This involves in particular the use of optimization, parameter identification, and model reduction techniques in attempts to increase the amount of oil or gas that can be recovered from subsurface hydrocarbon reservoirs. Other applications involve the control of ground water flow for drinking water or pollution control, and the subsurface storage of CO2. The dynamic behavior of subsurface multi-phase porous media flow is typically simulated with large-scale nonlinear numerical models, containing up to millions of state variables and parameters. Moreover, a typical characteristic of these models is a very large uncertainty in the parameter values, reflecting the very large geological uncertainty of the subsurface. Traditionally they are primarily used for 'field development', i.e. the engineering of well configurations and production strategies, but an emerging use is in the 'real-time' optimization and control of oil production, known as 'closed-loop reservoir management (CLRM)'. In this paper we describe some recent contributions of our group to the use of systems and control theory for CLRM. This concerns sequential and multi-level production optimization, identifiability of model parameters, and 'control-relevant' upscaling.

09:15-10:00 FrPlT3.2

Challenges of Modeling Drilling Systems for the Purposes of Automation and Control, pp. 201-210

Downton, Geoff Schlumberger

To fully model every aspect of the process of drilling a borehole is still in the realms of research. Great strides are being made to develop high-fidelity models of well-defined domains such as the rig systems, drillstring, rock-bit interaction, fluid control systems and the Earth. Bringing all these models together in any unified manner and proposing a unified control solution to fully automate the whole process is still an exploratory venture. The uncertainty prevailing over the magnitude and spatiotemporal distribution of disturbances to be controlled or rejected by systems best described by non-linear partial differential equations rather than linear approximations, makes for a very challenging control problem. This uncertainty also raises interesting questions on how detailed the models need to be and how this might change our approach to modeling in the future. However technology is never static and certain developments are currently in play that will dramatically improve our capacity to model and control processes which are currently considered too complex to control.

FrAT1 EL5

Drilling Hydraulics (Regular Session)

10:20-10:40 FrAT1.1

A Simplified Model for Multi-Fluid Dual Gradient Drilling Operations, pp. 211-216

Stamnes, Øyvind Nistad Ocean Riser Systems
Mjaavatten, Erlend Ocean Riser Systems
Falk, Kristin Ocean Riser Systems

Dual gradient drilling (DGD) is a method for drilling deep water offshore wells safely, efficiently, and to a reduced cost. The dual gradient effect is enforced by using a heavy fluid fitting the drilling window, and a subsea pump to lift the returns up to the rig. Automatic control of this pump is fundamental to ensure a safe and efficient dual gradient drilling operation. In this paper we extend existing work on modelling for DGD in two ways. Firstly, we present a simplified model for operational scenarios where there are multiple fluids in the well, e.g. when changing drilling fluids. Secondly, we make the model more realistic by including a model of the centrifugal subsea pump. The resulting model is then used to simulate a scenario with changing of drilling fluid, and where a PI controller is used to maintain a constant downhole pressure. The simulation confirms that the model is reasonable, and that the PI controller is able to maintain a near constant downhole pressure throughout the operation.

10:40-11:00 FrAT1.2

Utilizing Instrumented Stand Pipe for Monitoring Drilling Fluid Dynamics for Improving Automated Drilling Operations, pp. 217-222

Carlsen, Liv Almås IRIS
Nygaard, Gerhard International Res. Inst. of Stavanger
Time, Rune W. Univ. of Stavanger

This paper introduces a method to enable automatic updates of the density, compressibility and frictional effects of the drilling fluid during a drilling operation. By placing pressure sensors along the circulation path from the mud pump to the connection to the drillstring, the fluid dynamics can be examined more thoroughly at various flow rates and pressures. This will help filling the gap of reliable data on drilling fluid properties, which is of great importance in automated drilling operations.

11:00-11:20 FrAT1.3

New Choke Controller for Managed Pressure Drilling, pp. 223-230

Reitsma, Donald Schlumberger
Couturier, Yawan Schlumberger

Managed Pressure Drilling (MPD) is performed in offshore and onshore oil and gas areas to reduce the risks that may be associated with using conventional drilling hydraulic methods. The aim of MPD is to reliably and precisely control the pressure at the bottom of well within what is known as the ‘pressure window'. Manual control of the choke valve was adapted from manual well control methods developed for circulating out an oil or gas influx. There have also been attempts dating back more than 40 years to automate the choke controller for influx circulation, though as of today there is still not a reliable automated system available for this purpose. Over the last ten years, MPD systems with various levels of automation have been developed. The current automated MPD system has been successfully used worldwide to drill hundreds of wells with narrow pressure windows. This paper discusses the development history and the newest developments in automated choke control with a forward-looking view of automated processes to precisely manage well pressure.

11:20-11:40 FrAT1.4

Safe Mud Pump Management While Conditioning Mud, pp. 231-238

Cayeux, Eric International Res. Inst. of Stavanger

For complex drilling operations with narrow geo-pressure windows, it is not uncommon to have problems with formation fracturing, due to erroneous mud pump management. To assist the driller in managing the circulation, it is possible to limit both the acceleration of the mud pumps whilst changing the flow-rate as well as the actual flow-rate, to avoid generating downhole pressure above the fracturing pressure gradient of the open hole section. Such mud pump operating limits are dependent on the operational parameters (e.g. drill-string axial and rotational velocities), and the in situ conditions downhole. The in situ conditions evolve with time due to the changes of bit and bottom hole depths as well as the variations in temperature, mud properties and cutting concentrations. When starting to condition mud after a long period of time without circulation, the changes in temperature can be very large. Furthermore, in the eventuality of barite sag, lifting up drilling fluids containing a large concentration of high gravity solid can cause much increase of the downhole pressure. This paper presents a methodology that is used in an

automatic drilling control system to account for all those factors in order to have a safe mud pump management including circumstances where mud is being conditioned.

11:40-12:00 FrAT1.5

Suppression of Heave-Induced Pressure Fluctuations in MPD, pp. 239-244

Mahdianfar, Hessam	Norwegian Univ. of Science and Tech. (NTNU)
Aamo, Ole Morten	NTNU
Pavlov, Alexey	Statoil ASA

A model describing the flow and pressure fluctuations in the bore-hole due to drill-string movement has been presented. It consists of a pair of coupled nonlinear partial differential equations modelling the distributed pressure and flow in the well, and a superposition of multiple sine waves for the disturbance. Considering only top-side flow and pressure as measurements, it is shown that the model can be represented by a linear time invariant finite-dimensional system with output delay. This result is achieved by linearization and de-coupling using Riemann invariants. An infinite-dimensional observer is designed that estimates the disturbance, and the estimate is used in a controller that rejects the effect of the disturbance on the down-hole pressure. A model reduction technique based on the Laguerre series representation of the transfer function is used to derive a finite-dimensional, rational transfer function for the controller. The performance of the full-order and reduced-order controllers are compared in simulations, which show satisfactory attenuation of the heave disturbance for both controllers.

FrAT2 EL6

Compressor Control (Regular Session)

10:20-10:40 FrAT2.1

Hybrid Monitoring of Offshore Compression Systems, pp. 245-250

Miyoshi, Simone	Federal Univ. of Rio de Janeiro
Zyngier, Danielle	Federal Univ. of Rio de Janeiro
Souza Jr., Maurício	Federal Univ. of Rio de Janeiro
Secchi, Argimiro R.	PEQ - COPPE/UFRJ
Teixeira, Alex	Petroleo Brasileiro S.A. (Petrobras)
Campos, Mário	Petroleo Brasileiro S.A. (Petrobras)
Lima, Enrique	Federal Univ. of Rio de Janeiro

In this work a hybrid methodology based on statistical approach and phenomenological modeling was developed aiming the monitoring of the performance of compression equipment in an offshore oil platform. A rigorous model was employed in order to estimate thermodynamic based values of the performance of the compression system, given by the polytropic efficiency and head. Residuals were generated by comparing the model values with the ones which were calculated from manufacturer's curves using process data (suction and discharge pressures and temperatures, turbine rotation and suction flow). Even though the monitoring technique developed is essentially multivariable and dynamic, the results are displayed using typical univariate process control charts, providing a friendly interface for the operator and allowing the clear detection of process faults.

10:40-11:00 FrAT2.2

Model Predictive Anti-Surge Control of Centrifugal Compressors with Variable-Speed Drives, pp. 251-256

Cortinovis, Andrea	ABB Switzerland Ltd.
Pareschi, Diego	ABB Italy
Mercangöz, Mehmet	ABB Switzerland Ltd.
Besselmann, Thomas	ABB Switzerland Ltd.

In this article torque assisted anti-surge control (TASC), a compressor anti-surge control system based on model predictive control (MPC) is presented. TASC is implemented on an embedded system for the control of compressor stations with electrical variable-speed drives (VSD) which are used in applications such as natural gas transportation via pipelines. The manipulated variables of the proposed advanced controller are the electric motor torque and the position of a recycle valve, whereas the measured quantities are the same as those of a typical compressor control application including the pressure ratio and the gas flow. The TASC scheme uses the linear approximation of a nonlinear dynamic model to predict the behavior of the compression system. The information contained in the compressor map is incorporated into the nonlinear model as a 3rd order polynomial approximation. The surge line is taken into account as a constraint in the MPC formulation. Control action is calculated by solving an optimization problem in real-time at the control unit level with cycle times as low as 20 ms. The potential benefits of the proposed control strategy are evaluated in a simulation scenario corresponding to a potential deep surge event typically used in anti-surge control validation exercises. The simulations are carried out in a hardware-in-the-loop setting. In the evaluation, the performance of TASC is compared to a conventional anti-surge control approach. Due to the predictive capability and the manipulation of the motor torque, TASC is observed to achieve a safer and more efficient operation of the compressor station.

11:00-11:20 FrAT2.3

Energy Efficient Pump Control for an Offshore Oil Processing System, pp. 257-262

Yang, Zhenyu	Aalborg Univ.
Soleiman, Kian	Rambøll Oil & Gas A/S
Løhndorf, Bo	Rambøll Oil & Gas A/S

The energy efficient control of a pump system for an offshore oil processing system is investigated. The seawater is lifted up by a pump system which consists of three identical centrifugal pumps in parallel, and the lifted seawater is used to cool down the crude oil flowing out of a three-phase separator on one of the Danish north-sea platform. A hierarchical pump-speed control strategy is developed for the considered system by minimizing the pump power consumption subject to keeping a satisfactory system performance. The proposed control strategy consists of online estimation of some system operating parameters, optimization of pump configurations, and a real-time feedback control. Comparing with the current control strategy at the considered system, where the pump system is on/off controlled, and the seawater flows are controlled by a number of control valves, the proposed control strategy has showed significant energy savings without sacrificing the system performance.

11:20-11:40 FrAT2.4

Introducing Back-Up to Active Compressor Surge Control System, pp. 263-268

Uddin, Nur	Norwegian Univ. of Science and Tech. (NTNU)
Gravdahl, Jan Tommy	Norwegian Univ. of Science & Tech.

A novel method for introducing a back-up system to an active compressor surge control system is presented in this paper. Active surge control is a promising method for extending the compressor map towards and into the unstable area at low mass flow by stabilizing the surge phenomenon. The method also has potential for allowing operation at higher efficiencies. However, a failure in the active surge control system may endanger the compressor by entering deep surge as the compressor is allowed to operate in the stabilized surge area. We propose the use of a back-up system applied to the active system to keep the compressor safe should the active system fail. This paper present an active compressor surge control system with piston actuation combined with a blow off system as the back-up. Performance of the combined system is evaluated by simulating the system in situations where the piston is saturated or jammed. The combination results in a system with increased performance by taking advantage of both systems.

11:40-12:00 FrAT2.5

On-Line Calibration Monitoring System Based on Data-Driven Model for Oil Well Sensors, pp. 269-274

Boechat, Andre A. Federal Univ. of Santa Catarina
Moreno, Ubirajara F. Federal Univ. of Santa Catarina
Haramura, Decio, Jr. Federal Univ. of Santa Catarina

In the oilfield industry, data collected from well sensors plays an important role in performance and security applications. The quality of the measurements is directly related to the accuracy of the control actions and the optimisation of the production. On-line calibration monitoring systems can determine drifts in the sensors measurements and provide more reliable information to the user. In this paper, a robust on-line calibration monitoring system for drift correction/detection in well sensors is presented and evaluated for simulated and real data sets. Comparisons with a state-of-art monitoring system is also showed. The results indicate a promising applicability of the calibration monitoring system for the oilfield industry data.

FrBT1 EL5
Optimization and Control (Regular Session)

13:30-13:50 FrBT1.1

Optimization of a Simulated Well Cluster Using Surrogate Models, pp. 275-280

Grimstad, Bjarne IO-Center, NTNU and ITK, NTNU
Gunnerud, Vidar NTNU
Ljungquist, Dag FMC Tech.
Ausen, Håvard NTNU
Lervik, Victoria NTNU

In this paper we present an implementation of a partly Derivative-Free Optimization (DFO) algorithm for production optimization of a simulated multi-phase flow network. The network consists of well and pipeline simulators, considered to be black-box models without available gradients. The algorithm utilizes local approximations as surrogate models for the complex simulators. A Mixed Integer Nonlinear Programming (MINLP) problem is built from the surrogate models and the known structure of the flow network. The core of the algorithm is IBM's MINLP solver Bonmin, which is run iteratively to solve optimization problems cast in terms of surrogate models. At each iteration the surrogate models are updated to fit local data points from the simulators. The algorithm is tested on an artificial subsea network modeled in FlowManagerTM, a multi-phase flow simulator from FMC Technologies. The results for this special case show that the algorithm converges to a point where the surrogate models fit the simulator, and they both share the optimum.

13:50-14:10 FrBT1.2

Problems of Identification of Hydrodynamic Models in Reservoir Engineering, pp. 281-285

Akhmetzyanov, Atlas Inst. of Control Sciences, Russian Acad. of Sciences
Salnikov, Anton Inst. of Control Sciences, Russian Acad. of Sciences

The need for solving the problem of identification of basic parameters (permeability coefficients, initial and boundary conditions) for hydrodynamic models of reservoirs on retrospective data arises from incompleteness and observational errors in source and current information about controlled object at all stages of reservoir engineering. Iterative methods for simultaneous solving of direct and inverse problems for original model equations on retrospective data are proposed to solve the problems of identification and adaptation of initial and boundary conditions and filtration parameters. Parallel computing technologies with optimal hierarchical (multilevel) embedding of algorithms into the architecture of supercomputers are offered for creation an integrated model of complex technological system.

14:10-14:30 FrBT1.3

Oil Reservoir Production Optimization Using Single Shooting and ESDIRK Methods, pp. 286-291

Capolei, Andrea Tech. Univ. of Denmark (DTU)
Völcker, Carsten Tech. Univ. of Denmark
Frydendall, Jan Tech. Univ. of Denmark
Jorgensen, John Bagterp Tech. Univ. of Denmark

Conventional recovery techniques enable recovery of 10-50% of the oil in an oil field. Advances in smart well technology and enhanced oil recovery techniques enable significant larger recovery. To realize this potential, feedback model-based optimal control technologies are needed to manipulate the injections and oil production such that flow is uniform in a given geological structure. Even in the case of conventional water flooding, feedback based optimal control technologies may enable higher oil recovery than with conventional operational strategies. The optimal control problems that must be solved are large-scale problems and require specialized numerical algorithms. In this paper, we combine a single shooting optimization algorithm based on sequential quadratic programming (SQP) with explicit singly diagonally implicit Runge-Kutta (ESDIRK) integration methods and the a continuous adjoint method for sensitivity computation. We demonstrate the procedure on a water flooding example with conventional injectors and producers.

14:30-14:50 FrBT1.4

A Computational Analysis of Convex Combination Models for Multidimensional Piecewise-Linear Approximation in Oil Production Optimization, pp. 292-298

Silva, Thiago L. Federal Univ. of Santa Catarina
Codas, Andrés UFSC
Camponogara, Eduardo Univ. Federal de Santa Catarina

The lift-gas allocation problem with pressure-drop constraints and well-separator routing is a mixed-integer nonlinear program considerably hard to solve. To this end, a mixed-integer linear programming formulation was developed by multidimensional piecewise-linearization of pressure drop functions using standard (CC) and logarithmic (Log) aggregated models. These models were compared by means of a computational analysis, which indicates that the logarithmic model is faster than the standard one possibly because of the reduced number of variables and constraints.

FrBT2 EL6
Control of Mechanical Systems (Regular Session)

13:30-13:50 FrBT2.1

Tool-Point Control for a Redundant Heave Compensated Hydraulic Manipulator, pp. 299-304

Kjelland, Magnus Berthelsen Univ. of Agder
Tyapin, Ilya Univ. of Agder
Hovland, Geir Univ. of Agder
Hansen, Michael Rygaard Univ. of Agder

Abstract: In this paper, theoretical and experimental implementation of heave compensation on a redundant hydraulically actuated manipulator with 3-dof has been carried out. The redundancy is solved using the pseudo-inverse Jacobian method. Techniques for minimizing velocities and avoiding mechanical joint saturations is implemented in the null space joint motion. Model based feed-forward, combined with a PI-controller handles the velocity control of each joint.A time domain simulation model has been developed, experimentally veried, and used for controller parameter tuning. Model verication and experimental results are obtained while the manipulator is exposed to wave disturbances created in a dry environment by means of a Stewart platform.

13:50-14:10 FrBT2.2

Motion Planning and Tracking of Subsea Structures, pp. 305-309

Fortaleza, Eugenio Univ. de Brasilia

This article uses an active control dedicated to the positioning of subsea structures like flow lines. This kind of operation consists in connecting the bottom end of a very long pipeline to the wellhead,

by dynamically modifying the pipeline top end position, which is linked to a Dynamically Positioned Vessel (DPV). Such long pipelines are usually called risers, because they are used to rise the drilling mud or the hydrocarbons from the wellhead to the platform. Nowadays this operation is often done manually. The use of an active control intends to reduce the operation time, and to make it possible even under bad weather conditions. The considered subsea structure can be aproximated as a cable submerged in a flow and modelled by the Bernoulli cable equation, completed with a damping factor, that linearly depends on the structure speed. This article tests previous works regarding the tracking system used to follow the reference trajectory of the motion planning considering the Euler-Bernoulli beam equation for large rotations, that is the most used model to define the dynamic behavior of this kind of structures.

14:10-14:30 FrBT2.3

Cascade Controller Including Backstepping for Hydraulic-Mechanical Systems, pp. 310-315

Choux, Martin	Univ. of Agder
Hovland, Geir	Univ. of Agder
Blanke, Mogens	Tech. Univ. of Denmark

Development of a cascade controller structure including adaptive backstepping for a nonlinear hydraulic-mechanical system is considered in this paper where a dynamic friction (LuGre) model is included to obtain the necessary accuracy. The paper compares the performance of two variants of an adaptive backstepping tracking controller with earlier results. The new control architecture is analysed and enhanced tracking performance is demonstrated when including the extended friction model. The complexity of the backstepping procedure is signicantly reduced due to the cascade structure. Hence, the proposed control structure is better suited to real-time implementation.

14:30-14:50 FrBT2.4

The Effect of Friction in Passive and Active Heave Compensation of Crown Block Mounted Compensators, pp. 316-320

Haaø, Jørgen	Univ. of Agder
Vangen, Steffen	Univ. of Agder
Tyapin, Ilya	Univ. of Agder
Choux, Martin	Univ. of Agder
Hovland, Geir	Univ. of Agder
Hansen, Michael Rygaard	Univ. of Agder

This paper studies the effects of friction model during passive and active heave compensation of offshore drilling equipment. The main purpose of heave compensation while drilling from vessels or semi-submersible platforms is to maintain the drilling operation unaffected by the wave induced motion. The investigated system is of an existing crown mounted compensator. A model of the system is developed which includes mechanics, hydraulics and pneumatics. The passive heave compensation scheme is described including force equalising hydraulic cylinders. In this paper the detrimental effect of friction on the heave compensation performance in both passive and active heave compensation is investigated and discussed.