NSERC INDUSTRIAL RESEARCH CHAIR
Control of Oil sands Processes

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Part of IRC Team

Success Stories

Ming Ma and Shekhar Sharma

Naphtha to Bitumen (N:B) ratio is a key quality variable in the Inclined Plate Settler (IPS) feed streams and has to be maintained at a certain level, so that efficient and economical separation of bitumen can be achieved. However, accurate lab measurements of N:B ratio can only be obtained at a relatively slow rate i.e. every few hours and with time delay, which cannot be used for real-time control. Thus, using first principles modeling and statistical analysis, an N:B ratio soft sensor has been developed to provide reliable and real-time N:B readings suitable for on-line monitoring and closed-loop control. The developed solution has been successfully used in closed-loop control since January, 2016 and has generated considerable economic benefits for our industrial partner.

Rishik Ranjan and Hashem Alighardashi

An Excel-based Graphical User Interface (GUI) that communicates with GAMS optimization software has been developed to perform data reconciliation and economic optimization of water flow network in SAGD operations. This tool enables optimization of different objectives such as maximizing steam production rate, minimizing steam production cost, and ensuring optimal operational strategies under planned shutdowns circumstances, while maintaining desired steam flowrates.

We are committed to continuous research and thrive for innovative solutions to economical, responsible, and sustainable development of oil sands process while ensuring safety by combining various aspects of process systems engineering including control, optimization, and data mining.

2016 IRC Renewal Kickoff Meeting

Robust Data Reconciliation, by Hashem Alighardashi

Process measurements which are collected from industrial plant operations are of vital importance for process identification, online optimization, and process control. Nonetheless, these measurements are inevitably contaminated by random errors and gross errors. Data reconciliation can improve the accuracy of measurements with the help of a process model. However, the existence of gross errors in the data limits the application of conventional data reconciliation approaches due to smearing effects. Hence, the focus of this project is to formulate a data reconciliation framework which can omit gross errors besides random errors achieving robust data reconciliation.

Introduction of state estimation under attacks, by Shunyi Zhao

Sensor attacks occur frequently on control systems, which may cause performance degradation and catastrophic events. The attack sources can generally be classified into three categories: (1), *malicious software* that can change sensor readings before it is processed by the control algorithms; (2), *network* meaning that an adversarial attacker corrupts sensor measurements by manipulating the data packets exchanged between various components; (3), *sensor spoofing* meaning that an attacker can mislead the sensor about the values of the physical signals being sensed by tampering with the sensor hardware. The main goal of this project is to determine which sensors are under attack and also design a secure state estimator when sensors are attacked. The challenge now is that the previous adversaries were accidental, instrument failures, etc., but now they are intentional actions made by expert attackers who may know the weakness of the whole system.

Electric Submersible Pump Monitoring, by Rahul Raveendran

Electric Submersible Pumps Monitoring (ESPs) are installed in producer wells of steam assisted gravity drainage (SAGD) plants to provide artificial lift. As ESPs are exposed to harsh well conditions such as extreme temperatures, high gas/water to oil ratio, sanding, etc., they suffer from component failures and shorter run life, leading to high workover/replacement costs, production downtime, etc. This project involves developing a data driven tool for detecting harsh well conditions, predicting ESP failures upfront and establishing recommendation system for safeguarding ESPs from failures.

Distributed state estimation for nonlinear large-scale systems, by Mohammad Rashedi

Rather than using centralized framework to estimate unmeasurable states of large-scale systems such as SAGD process, distributed framework is considered in this project. The benefit of the latter framework is that it surpasses the centralized one in terms of fault tolerance and computational complexities as proven by simulation results. States required for SAGD monitoring and control include steam chamber volume, sub-cool temperature, and steam quality in steam generator and steam injector.

2016 IRC Renewal Kickoff Meeting (cont.)

Process data analytics toolbox, by Yujia Zhao

The process data analytics toolbox is a GUI that assists researchers and engineers to visualize, analyze, and model their data. Various visualization methods are provided and the proposed data analysis tool enables the user to perform clustering, correlation, time delay, and dimensionality reduction. The toolbox uses regression methods to identify various linear and nonlinear models. The toolbox is developed in both MATLAB and Python, and is available for both researchers in the educational institutions and engineers in industry.

Contribution on stochastic MPC method, by Wenhan Shen

Unlike traditional constrained Model Predictive Control (MPC), chance constrained stochastic MPC deals with control problems under uncertainty. In this project, a robust optimization method is proposed to handle individual and joint chance constraints in the stochastic MPC problem. Further, the proposed robust optimization method assumes arbitrary noise distributions and is not limited to simplified assumptions. The proposed method has been applied to a simulated SAGD process and the results indicate that constraint violations have been reduced compared to traditional MPC framework.

Soft sensor analytics toolbox, by Ming Ma

Soft sensor analytics is a graphic user interface that assists in soft sensor development using input-output data. This tool enables users to process data using multiple packaged methods. Users can then obtain mathematical models by using different predefined algorithms and test them on different data sets. The development environment is Python which is free open-source software. The distribution format of our soft sensor analytics software is an executable file that does not require installation of any other software.

Online operating optimality assessment, by Shabnam Sadeghi

Industrial process operations may deviate from the preliminary design over time due to disturbances and/or changes in process condition. Such circumstances would affect the desired optimal performance**.** Therefore, in this project, we develop a systematic method for online optimality assessment based on operating data. The proposed method enables us to identify operating modes, operating regions, predict performance, detect the cause of non-optimum performance, and propose preliminary suggestions to improve the performance. The developed method is simulated on a water treatment network plant in the SAGD process and demonstrated satisfactory results.

Soft Sensor Modelling by, Yanjun Ma

To ensure safety and minimal energy consumption in process industries, quality variables are required to be estimated correctly by means of soft-sensing when hardware sensors are not available. Soft sensors are generally developed by combining first-principles concepts, typically mass and energy balance, with data-driven techniques including latent variable modeling. After successful integration of these approaches, our group has delivered several soft sensors successful applications such water content of SAGD emulsion, steam quality of OTSG outlet, and many others. Online testing results of our developed softs sensors have showed better prediction performance compared to current commercial models in use.

Diagnosis analytics toolbox, by Elham Naghoosi

The toolbox aims to help engineers with fault detection and diagnosis by providing two GUIs, one for causal analytics and the other for oscillation diagnostics. The causal analytics GUI detects the causal relations between process variables and estimates the strength of the relations. The oscillation diagnostics GUI helps with detection of oscillations in process variables and identifies whether the oscillations are caused by controller tuning, valve non-linearity, or by an external disturbance.

Robust probabilistic principal component analysis for process modeling subject to scaled mixture Gaussian noise, by Anahita Sadeghian

Conventionally, for probabilistic principal component analysis (PPCA) based regression models, noise with a Gaussian distribution is assumed. This assumption makes the model to be vulnerable to large random errors, known as outliers which usually occur due to irregular process disturbances, instrumentation failures, or transmission problems. Outliers are common in process industries; therefore, handling this issue is of practical importance. In this project, unlike the conventional noise assumption, a mixture noise model with a contaminated Gaussian counterpart is adopted to diminish the adverse effects of outliers. In comparison with conventional model, the developed robust model has improved performance and results are published in a peer reviewed journal.

2016 IRC Renewal Kickoff Meeting (cont.)

PSV interface level detection and estimation using image processing, by Zheyuan Liu

The interface level between froth and middling layer in the primary separation vessel (PSV) plays a significant role on overall bitumen recovery. Hence, the estimation of the interface level is a key variable for controlling the interface level itself and for maintaining better overall bitumen recovery. Currently, a camera is used in industries for interface detection. To improve the accuracy of camera image-based detection, Markov random field (MRF) based image processing method is proposed to estimate the interface level. A pilot-scale laboratory experiment was designed to simulate the industrial scenario by creating an interface between oil and water. An online camera was employed to capture the image and the proposed approach was applied. The results demonstrated the effectiveness of the proposed image segmentation approach for detecting and estimating the interface level.

Electricity price prediction tool by, Ouyang Wu and Nabil Magbool Jan

Due to the deregulation of electricity markets in Alberta, forecasting pool price is of interest for maximizing the economic potential of industries. Therefore, this project aims to develop a more accurate predictive model of pool price that can be used in real time to enable industry to adjust its bidding strategy and optimally schedule the consumption such that the profit is maximized. For online prediction of pool price, the predictive tool is Excel-based and has been built-in with the important functionalities including, automatically retrieves the real-time data from AESO website, performs pool price prediction, and provides historical performance statistics of the electricity prediction model. The performance of the proposed tool is tested on the recent three years data and the predictions appear to be better than pool price forecast provided by the system operator AESO.

PSV interface detection, by Fadi Ibrahim

PSV Froth-Middling (FM) interface is a key variable to be measured and hence controlled. Accurate measurements of the interface are available using a camera that reads it through a sight glass. However, camera readings can be occasionally absent due to blocked sight glass. The objective of this project is to use reliable profiler measurements including density and temperature to estimate the FM interface when the camera readings are not available. The method used is Recursive PLS where the model is trained by means of regression between the profiler and the camera measurements with the advantage of being simple enough for online implementation. Online simulated results show that the estimated interface accurately follows the reference even at one hour after losing camera measurement.

IRC Process System and Control Laboratory

Our lab has been recently been equipped with a new plant, which is used to simulate and experimentally study the interface level monitoring for the primary separation vessel (PSV) in industry. As shown in the figure, there is a main vessel and two holding tanks. The main vessel simulate the PSV and two immiscible process liquids, purified water and sunflower oil, are filled in the vessel to form an interface. Since sunflower oil has relative low density, it represents the froth layer in real PSV and purified water represents the middling layer. Two pumps are also equipped to drain two liquids from the main vessel into two holding tanks separately. Other two pumps are equipped to pump out two liquids from holding tanks and recycle them as the input of the main vessel. Interface level is monitored using a DP cell as well as an online camera and is controlled to be maintained at a relatively constant position by manipulating water drainage pump rate. The plant has already been built up and can be operated using LabView. In future, it well be connected with MATLAB through OPC. The captured images are analyzed using Markov random field (MRF) theory to estimate the interface.

Introducing Researchers

Elham Naghoosi

joined Prof. Huang's group as a PhD student in 2012 and has successfully graduated in 2016. Her research is mainly focused on developing novel and reliable algorithms for causality analysis as well as oscillation detection and diagnosis. Parts of her results were published in several accredited journals such as IEEE transactions on Control Systems Technology and Journal of Process Control. In addition, the algorithms she developed are being programmed in a user friendly GUI that can be used by researchers and engineers. Moreover, Elham has been productively involved in several industrial projects, such as estimating bitumen content in tailings and studying the influence of caustic addition on bitumen recovery.

Yujia Zhao

began his M.Sc. in Prof. Huang's group in 2013 and has successfully graduated in 2016. His contributions in theoretical research and practical projects include time-varying time delay estimation, robust parameter estimation, and data analytics in oil sands industries. His theoretical studies have led to publications in high ranked journals such as IEEE Transactions on Industrial Electronics and IEEE Transactions on Cybernetics.

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Publications

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