NSERC INDUSTRIAL RESEARCH CHAIR *Control of Oilsands Processes*

NEWS LETTER, IRC AND RELATED R&D ACTIVITIES, ISSUE 5, May 2014

The search for solutions to the oil sands development has typically focused on the processes that make up an oil sands operation. We take a different approach by focusing on the systems that control these processes.

Dr. Huang has been granted the 2014 APEGA Summit Awards in Research Excellence. Photo is taken from the award ceremony held in Edmonton on April 2014. From left to right: Dr. Wanke, Dr. Huang, Dr. Forbes, and Dr. Shah.

Success Stories

Xianqiang Yang

has developed a sulfur content inference soft sensor for the Gas Oil Hydrotreater (GOHT) unit to provide on-line predictions of the sulfur content in gas oil product. The inferential model is constructed after key variables selection and the recursive model parameter update strategy is adopted to handle the time-varying behaviors of the process. The soft sensor has been put online since July, 2013 and the performance of the soft sensor is satisfactory. The development of the closed loop control of the sulfur content based on this soft sensor is under way.

2014 Spring IRC Progress Meeting and Workshop

A Case Study of Early Fault Detection and Isolation, by Ruben Gonzalez

Abnormal process operation is being detected in a Tail Gas Treatment Unit (TGTU) and in the three upstream Sulphur Recovery Units (SRUs). Kernel Density Estimation (KDE) is proposed as an alternative to Principal Component Analysis (PCA) because KDE does not require any assumptions about the distribution taken by the data and by the relationships the variables have with each other; recall that PCA requires the assumption that data follows a Gaussian distribution and that relationships have to be linear. One difficulty with applying KDE is that it has poor performance in higher dimension and it cannot be used to single out locations of abnormalities (such as measurements most affected). Nevertheless, when combined with Bayesian Networks, dimensionality can be drastically reduced, and the Bayesian Network can effectively single out the problem sources by making use of process knowledge and causal relationships. This method has been effectively applied to the TGTU and SRU system where abnormalities were successfully detected with a tenfold reduction in false positives over the current PCA method.

Sanding Detection and Monitoring of the Critical Minimum Velocity in the Primary Separation Vessel Underflow Line by, Nima Sammaknejad

Sand deposition and pipeline plugging, also known as the "sanding phenomena", have always been an important issue in oil-sand processes. There have been numerous efforts to provide conditions to ensure safe operations in the design of tailing pipelines which usually contain around 60 (Wt%) solid. However, most of the studies are for the design step and usually ignore the dynamics of the process. The critical minimum velocity in slurry transport is defined as the velocity in which the solids form a moving bed at the bottom of the pipe from fully suspended flows. Velocities higher than the critical minimum velocity usually ensure safe operations. The critical minimum velocity is a function of many different input variables. Among all these inputs, only the fast rate data for the carrier fluid and mixture density are available online. In this study, a novel method for on-line estimation of the critical minimum velocity with application to the PSV unit is proposed. A soft sensor is developed to correct the measurements of the middling density (carrier fluid density) on-line analyzer. A probabilistic approach is proposed to avoid the unnecessary alarms during the on-line application. The proposed method shows satisfactory estimations for the critical RPM in the underflow pipeline.

The Soft Sensor for 90% Boiling Point of Kerosene in Diluent Recovery Unit (DRU), by Kangkang Zhang & Xianqiang Yang

A new soft sensor for 90% boiling point of side stripper kerosene from diluent recovery unit (DRU) has been developed. In practice, the 90% boiling point is only available in slow rate through lab analysis. In order to develop the inferential model, the key input variables selection is first performed based on correlation analysis and some suggestion from our collaborating industry. The chosen key inputs are then used to construct the inferential model and the model parameters are estimated. The model parameters are fixed and only the bias term is updated online dynamically. This new soft sensor has been put online since Feb 5, 2014 and performance has been satisfactory.

2014 Spring IRC Progress Meeting and Workshop (cont't)

Froth Pipeline Water Content Soft Sensors and Control, by Yu Miao

The objective of this project is to provide real-time monitoring and automatic control of froth water content for froth pipeline operations. Two hardware water meters have been installed for on-line measurement of water content. However, they are not reliable in providing real-time information. Lab data is also available for the unit; however, the value is obtained off-line with a large sampling time and time delay, and therefore it is not appropriate for closed-loop control. To achieve the goal of the project, two soft sensors based on dynamic first principle model of the process have been developed. The soft sensors work reliably, and their accuracy has been verified by the lab data. Based on the soft sensors, a feed-forward & feed-back cascade control strategy has been implemented for hot processing water addition so that water content in froth pipeline can be controlled within the desired range. The soft sensors and the control were successfully implemented about 6 month ago and have been working very well almost all the time. The result shows that the froth water content is significantly reduced, which has led to great economic benefit.

IPS Naphtha to Bitumen Ratio Soft Sensors, by Ming Ma & Shima Khatibisepehr

The product N:B is a key variable which needs maintaining at certain levels so as to achieve effective separation at an affordable cost. But the N:B is not available "on demand" and is available only after several hours of laboratory analysis. The objective of this project is to develop and implement a soft sensor that provides fairly accurate real-time IPS Product N:B estimates. The development of soft sensor has been done by applying advanced statistic techniques and first principles theory. The soft sensor is being tested on-line under stewardship of industrial partners. In order to cope with the time-varying behavior of the process, on-line adaptations are integrated in the implementation procedure by using recursive Prediction Error Method and Dynamic Bias Update Method, respectively. Moreover, robust layers and cautious update strategy are applied in adaptive sensors to detect and filter abnormal input measurement and lab data of product N:B. According to the recent stewardship results (from Dec. 2013 to April. 2014), the adaptive soft sensors produce accurate and reliable estimates.

Plant Wide Data Mining Optimization (PWDMO), by Alireza Fatehi

Individual units and equipment in process plants are highly interactive. So, plant wide analysis is required to optimize the process operation. Up to now, four Plant-Wide Data Mining Optimization (PWDMO) approaches have been considered, including computing optimal operating point, low performance detection and diagnosis, forward prediction, and set point trajectory computation. Beside the introduction of each of them, a plant wide data mining diagnosis (PWDMD) approach is presented and applied to an oil sands process. In PWDMD, when a fault is detected in one of the variables, all other variables in the process are analyzed for the same abnormal behavior. Then, a cause-effect analysis is performed on those variables with the same abnormal behavior to diagnose the origin of the faulty behavior. This general technique is employed to diagnose a background high fluctuation in some of the variables of the upgrading plant. The analysis reveals that the origin of the fluctuation was in one of the diluent recovery units (DRU), and the discovery has been verified by plant personnel.

Plant-wide Oscillation Detection and Diagnosis, by Elham Naghoosi

Oscillations happen in control loops of industrial plants due to various reasons such as poor controller tuning, external oscillatory disturbances or control valve problems. Regardless of the cause, oscillations disturb the normal plant operation imposing a poor operation condition. Detection and diagnosis of propagated oscillations in process variables is a challenging but important task. A method is proposed that utilizes the auto correlation function of variables to detect the oscillatory variables and estimate the oscillation periods in the presence of multiple oscillations. The advantage of the developed method is that it requires no or little human interference in the detection process. Diagnosis of the oscillation is the next step in plant-wide oscillation detection and diagnosis. Diagnosing which element in the loop is causing the oscillation helps in selecting the appropriate troubleshooting procedure. Controller re-tuning is the most common approach to resolve oscillations. However, it may not be effective when the oscillation is externally entering the loop or is due to valve stiction. A method is proposed to distinguish between controller induced oscillations and externally introduced harmonics.

Near Infrared Spectroscopy Modeling and Prediction, by Mulang Chen, Swanad Khare& Shima Khatibisepehr

Recursive algorithms with forgetting factor are well-known algorithms for on-line identification. It is seen that recursive algorithms are best suited when the underlying process is time varying. This approach is not very effective when the underlying process is non-linear. To this end, Just-In-Time (JIT), also known as locally weighted regression, modeling is of help. This approach finds the most relevant data to the current query from the historical data base. Using this data, a local model is built corresponding to the query. A unified approach is proposed which merges traditional recursive approach in JIT framework. This unified approach is capable of addressing variability in time as well as non-linearity issues in modeling. The usefulness of this approach is illustrated on an NIR industrial data set from a refinery. A key point in JIT modeling is similarity measure. In the case of severe non-linearity in the process, one needs to include the information of output space in the proposed similarity measure. This information ensures that the points similar in input space are such that the corresponding properties in output space are also similar. A similarity measure to serve this purpose is proposed using a mathematical technique known as Orthogonal Signal Correction (OSC). This OSC based similarity measure is integrated in JIT modeling approach to illustrate the better prediction performance on a benchmark pharmaceutical case study.

Introducing a researcher

Swanand Khare

Obtained his PhD degree in Electrical Engineering with specialization in control and computation from Indian Institute of Technology Bombay, India in July 2011.He then joined Prof. Huang's research group as a postdoctoral fellow. His research interests include data based estimation and identification, functional data analysis, numerical methods in systems theory focusing on applications in the area of chemical processes and bioinformatics. For the past two years, he has been a coordinator for IRC projects contributing to soft sensor development and plant-wide data mining and optimization. He mentored MSc students and collaborated actively with other group members resulting in a number of publications in reputed journals like Journal of Process Control, Computational Biology and Chemistry, Chemometrics and Intelligent Laboratory Systems. He has also taught a graduate level course on Numerical Methods at the University of Alberta.

News and Events

Events

Dr. Huang has received the 2014 **APEGA Summit Awards** in Research Excellence.

The Spring **IRC** Progress & Renewal Planning Meeting was held on May 1, 2014 at the University of Alberta. This meeting was followed by a Workshop on "**Process Control Solution for Industry**" with significant participation from industry.

News

Shima khatibisepehr, Ph.D. joined Enbridge

Jiusun Zeng, Ph.D. visiting Associate Professor from *Jiliang University, China*

Prakash Jagadeesan, Ph.D. visiting **Associate** Professor from *MIT Campus Anna University, India*

Recent Sample Journal Publications

E. Naghoosi, B. Huang, Automatic detection and frequency estimation of oscillatory variables in the presence of multiple oscillations**, Industrial and Engineering Chemistry Research,** 2014, V 53 (22), P 9427–9438

L. Chen, L. Han, B. Huang, F. Liu, Parameter estimation for a duel-rate system with time delay, **ISA Transactions,** 2014, P 1-9

Z. Xi, S. Khare, A. Cheung, B. Huang, T. Pan, W. Zhang, F. Ibrahim, C. Jin, S. Gabos, Mode of Action classification of chemicals using multi-concentration time-dependent cellular response profiles, **Computational Biology and Chemistry**, 2014, V 49, P 23-35

L. Chen, A. Tulsyan, B. Huang, F. Liu, Multiple model approach to non-linear system identification with uncertain scheduling variables using EM algorithm**, Journal of Process Control**, 2013, V 23 (10), P1480-1496

M. Keshavarz, B. Huang, Bayesian and Expectation Maximization methods for multivariate change point detection, **Computers & Chemical Engineering**, 2014, V 60, P339-353

A. Tulsyan, B. Huang, B. Gopaluni, F. Forbes, Performance assessment, diagnosis, and optimal selection of non-linear state filters, **Journal of Process Control**, 2014, V 24 (2) P 460-478

Z. Ge, B. Huang, Z. Song, Mixture semi-supervised principal component regression model and soft sensor application**, AIChE J**. 2014, V 60(2), P 533-545

X. Yang, B. Huang, V. Prasad, Inequality Constrained Parameter Estimation using Filtering Approaches, **Chemical Engineering Science**, 2014, V106, P 211-221

R. Gonzalez, B. Huang, Control loop diagnosis with ambiguous historical operating modes: Part 2, information synthesis based on proportional parameterization**, Journal of Process Control**, 2013, V 23(10), P1441-1454

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