Intelligent Alarm Management Techniques and Applications

Organizers & Speakers

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Summary

In the dynamic landscape of complex industrial facilities, effective alarm management is paramount to ensuring operational efficiency, safety, and overall system reliability. However, in real industries, alarm systems usually suffer from degraded performance due to alarm overloading and the presence of alarm floods. Thus, there is a strong need to develop and deploy intelligent alarm management tools, so as to improve the alarm system performance and reduce operators' workload. This workshop is meticulously crafted to address the unique challenges posed by the intricacies of modern industrial alarm systems. The workshop's primary objective is to empower industry professionals with the data analytic tools to navigate the complexities of alarm monitoring, ensuring not only compliance with industrial standards but also enhancing operational efficiency.

The workshop provides participants with a comprehensive understanding of intelligent alarm management strategies for complex industrial facilities. Participants will explore the nuances of alarm overloading, gaining insights into factors contributing to alarm overloading. Through an exploration of real-world scenarios, the workshop aims to highlight the tangible consequences of ineffective alarm management while emphasizing the need for intelligent solutions, such as pattern mining and deep learning for improvement of industrial alarm systems. The workshop will cover key topics, including the design of univariate/multivariate alarm systems, identification and reduction of nuisance alarms, root cause analysis by causality inference, pattern mining of alarm floods, alarm data visualization, and alarm system performance evaluation. The talks will be accompanied by industrial case studies to demonstrate the practical utility of these intelligent methods. The workshop aims to foster a collaborative learning environment, where participants can exchange experiences, strategies, and insights, ultimately leaving with the expertise needed to revolutionize alarm management practices in their industrial contexts.

Intended Audience

This workshop is tailored for a diverse audience, including industrial practitioners grappling with real-world alarm management challenges, vendors involved in the design of alarm systems, researchers investigating cutting-edge alarm management solutions, and graduate students keenly interested in the application of data science to address industrial problems.

Tentative Schedule

- 13:30 - 13:40 **Opening Remarks and Introduction**
  Tongwen Chen, University of Alberta, Canada
- 13:40 - 14:15 **Process Analytics Tools for Sensor Data, Alarm Data, and Operator Actions**
  Sirish L. Shah, University of Alberta, Canada
- 14:15 - 14:50 **Intelligent Alarm Management Toolbox Developed at the University of Alberta**
  Tongwen Chen, University of Alberta, Canada

- 14:50 - 15:25 **Identification of Nuisance Alarms and Logical Alarm Processing for Safe Plant Operations**
  Masaru Noda, Fukuoka University, Japan
- 15:25 - 15:35 Break
- 15:35 - 16:10 **Causality and Root Cause Analysis Based on Data Analytics**
  Fan Yang, Tsinghua University, China
- 16:10- 16:45 **Optimal Design of Industrial Alarm Systems Based on Process Knowledge and Historical Data**
  Jiandong Wang, Shandong University of Science and Technology, China
- 16:45 – 17:20 **Pattern Mining and Similarity Analysis for Industrial Alarm Flood Sequences**
  Wenkai Hu, China University of Geosciences, China
- 17:20 – 17:30 **General Questions and Answers, and Discussions**
  Moderated by Sirish L. Shah

Topics

The following topics will be discussed in this workshop. Each topic will be accompanied by industrial case studies to convey the practical relevance of intelligent industrial alarm monitoring and management techniques.

- **Process Analytics Tools for Sensor Data, Alarm Data, and Operator Actions**

The process industry is awash with all types of data archived over many years: sensor data, alarm data with operator actions to 'navigate' the process to operate safely at desired conditions and process models that are used for advanced control. The fusion of information from such disparate sources of process data is the key step in devising strategies for a smart analytics platform for safe and autonomous process operation. The purpose of this talk is to present results and strategies that will ultimately lead to safe and optimal autonomous or semi-autonomous process operation.

- **Intelligent Alarm Management Toolbox Developed at the University of Alberta**

This talk will summarize some recent results on advanced alarm analytics and present a new set of tools for design of alarm systems and improvement of alarm management. The essential functionalities of the tools include alarm visualization, alarm performance evaluation and analysis, and rationalization design, thereby to help industrial processes to comply with the new standards. The tools have been tested with real industrial data and used by process engineers in Canada and elsewhere.

- **Logical processing technique of nuisance alarms for safe plant operation**

Advances in distributed control systems in the chemical industry has made it possible to inexpensively and easily install numerous alarms in them. A poorly designed alarm system might cause nuisance alarms, which reduces the capability of operators to cope with plant abnormalities because critical alarms are hidden in them. In this presentation, a logical processing technique of nuisance alarms is introduced. Logical alarm processing is a technique for processing signals from alarm sensors to generate more meaningful alarms for plant operators. The effectiveness of the methods is evaluated for reducing nuisance alarms by simulation data of a chemical process.

- **Causality and Root Cause Analysis Based on Data Analytics**

This presentation will introduce advanced alarm strategy and abnormal situation monitoring based on process data analytics and, in particular, correlation/causality analysis based on mining of process and alarm data in combination with process connectivity knowledge, with applications to root cause analysis of propagated or even plant-wide abnormalities. The methods of Granger causality and transfer entropy will be demonstrated.

- **Optimal Design of Industrial Alarm Systems Based on Process Knowledge and Historical Data**

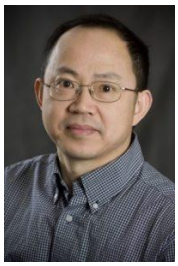
Industrial alarm systems need to be designed in an optimal manner, in order to reduce nuisance alarms and preserve true alarms. This presentation will focus on the optimal design of industrial alarm systems by exploiting process knowledge and historical data to distinguish normal and abnormal conditions. First, univariate alarm systems such as alarm delay times and alarm deadbands are investigated to dealt with different kinds of nuisance alarms. Second, multivariate alarm systems are designed based on normal operating zones, where dynamic alarm thresholds are developed for each process variable to tell operating conditions. Industrial case studies are provided to illustrate optimal design procedures of industrial alarm systems.

- **Pattern Mining and Similarity Analysis for Industrial Alarm Flood Sequences**

This presentation will introduce pattern mining and similarity analysis for industrial alarm floods, which are identified as the most difficult issues in industrial alarm monitoring and recognized as the leading causes of many industrial accidents. The involved methods include the sequence alignment based similarity analysis and some variants, similarity analysis with alarm encoding, alarm itemset pattern mining, and alarm sequential pattern mining. Such methods can learn meaningful patterns from historical alarm & event database, and the obtained results are helpful for further root cause analysis and early prediction of alarm floods.

About the Presenters

Tongwen Chen, University of Alberta, Canada



Tongwen Chen is presently a Professor and Tier 1 Canada Research Chair in Intelligent Monitoring and Control in the Department of Electrical and Computer Engineering at the University of Alberta, Edmonton, Canada. He received the B.Eng. degree in Automation and Instrumentation from Tsinghua University (Beijing) in 1984, and the M.A.Sc. and Ph.D. degrees in Electrical Engineering from the University of Toronto in 1988 and 1991, respectively. His research interests include computer and network based control systems, process safety and alarm systems, and their applications to the process and power industries. He has served as an Associate Editor for several international journals, including IEEE Transactions on Automatic Control and Automatica. He is a Fellow of IEEE, IFAC, Royal Society of Canada, as well as the Canadian Academy of Engineering.

Dr. Sirish L. Shah, University of Alberta, Canada

Sirish L. Shah is an Emeritus Professor with the Department of Chemical and Materials Engineering at the University of Alberta, where he held the NSERC-Matrikon-Suncor-iCORE Senior Industrial Research Chair in Computer Process Control from 2000 to 2012. He was the recipient of the Albright & Wilson Americas Award of the Canadian Society for Chemical Engineering (CSChE) in recognition of distinguished contributions to chemical engineering in 1989; the Killam Professor in 2003; the D.G. Fisher Award of the CSChE for significant contributions in the field of systems and control; the ASTECH “Innovations Prize in Oil Sands Research” in 2011; the 2014 IEEE Transition to Practice award of the control systems society and the RS Jane award of the CSChE in 2017. He is a fellow of the Canadian Academy of Engineering (FCAE) and IEEE. He currently holds a visiting appointment with the Digital Monozukuri (manufacturing) Education and Research Centre at Hiroshima University in Japan.

Masaru Noda, Fukuoka University, Japan

Masaru Noda is a Professor in the Department of Chemical Engineering at Fukuoka University, Japan. He received the B.Eng., M.Eng., and Ph.D. degrees in Chemical Engineering from Kyoto University in 1994, 1996 and 2000, respectively. His main research focus is on plant operational data analysis for safe process operation.

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Jiandong Wang is a Professor in the College of Electrical Engineering and Automation at the Shandong University of Science and Technology, Qingdao, Shandong Province, China. He received the B.E. in Automatic Control from Beijing University of Chemical Technology, Beijing, China, in 1997, and the M.Sc. and Ph.D. in Electrical and Computer Engineering from the University of Alberta, Canada, in 2003 and 2007, respectively. From 1997 to 2001, he was a Control Engineer with the Beijing Tsinghua Energy Simulation Company, Beijing, China. From December 2006 to October 2016, he was an Assistant/Associate/Full Professor with the College of Engineering, Peking University, China. His research interests include process control, industrial alarm systems, optimal scheduling and their applications to industrial problems. Dr. Wang has served as an Associate Editor/Guest Editor for Journal of Franklin Institute, Systems and Control Letters, and Control Engineering Practice.

Fan Yang, Tsinghua University, China

Fan Yang received the B.Eng. degree in Automation and the Ph.D. degree in Control Science and Engineering from Tsinghua University, Beijing, China, in 2002 and 2008, respectively. After working as a Postdoctoral Fellow with Tsinghua University and the University of Alberta, he joined the Department of Automation, Tsinghua University in 2011, where he is currently a Professor. His research interests include topology modeling of large-scale processes, abnormal events monitoring, process hazard analysis, and smart alarm management. He was a recipient of the Young Research Paper Award from the IEEE Control Systems Society Beijing Chapter in 2006, the Science and Technology Progress Award from the Chinese Association of Automation in 2018, the Zhang Zhongjun Excellent Paper Award in 2019, and the Teaching Achievement Awards from Tsinghua University in 2012, 2014, 2016, and 2019 and from the Chinese Association of Automation in 2016.

Wenkai Hu, China University of Geosciences, China

Wenkai Hu received the B.Eng. and M.Sc. degrees in Power and Mechanical Engineering from Wuhan University, Wuhan, Hubei, China, in 2010 and 2012, respectively, and the Ph.D. degree in Electrical and Computer Engineering from the University of Alberta in 2016. He was a Post-Doctoral Fellow from October 2016 to September. 2018, and a Research Associate from November 2018 to February 2019 at the University of Alberta. He is currently a Professor with China University of Geosciences, Wuhan, China. His research interests include advanced alarm monitoring, process control, and data mining for complex industrial processes. He has received several honors and awards, including the Hubei Outstanding Young Scholar, Chutian Young Elite, CUG Outstanding Young Talent, the 30th CPCC Zhang Zhongjun Excellent Paper Award, the IEEE-ICPS 2023 Best Paper Prize, the NCAA 2023 Best Paper Award, the First Award of CUG Young Faculties Teaching Competition in 2022, and the ISCIIA 2022 Best Presentation Award.

References

[1] Hu, W., Shah, S. L., & Chen, T. (2018). Framework for a smart data analytics platform for process monitoring and alarm management, *Computers & Chemical Engineering*. 114(9), 225-244.

[2] Parvez, M. R., Hu, W. & Chen, T. (2022). Real-time pattern matching and ranking for early prediction of industrial alarm floods. *Control Engineering Practice*, 120, 105004.

[3] Zhou, B., Hu, W., Brown, K., & Chen, T. (2021). Generalized pattern matching of industrial alarm flood sequences via word processing and sequence alignment. *IEEE Transactions on Industrial Electronics,* 68(10), 10171-10179.

[4] Wang, J., Yang, F., Chen, T. & Shah, S. L. (2016). An overview of industrial alarm systems: main causes for alarm overloading, research status, and open problems. *IEEE Trans. Automation Science and Engineering*, 3(2), 1045-1061.

[5] Wang, J., Wang, Z., Zhou, X., & Yang, F. (2022). Design of delay timers based on estimated probability mass functions of alarm durations. *Journal of Process Control*, 110, 154-165.

[6] Wang, Z., Noda, M. (2017). Identification of repeated sequential alarms in noisy plant operation data using dot matrix method with sliding window. *Journal of Chemical Engineering of Japan*, 50 (6), 445-449.

[7] Yang, F., Duan, P., Shah, S. L., & Chen, T. (2014). *Capturing Connectivity and Causality in Complex Industrial Processes*. Springer Science & Business Media.