Data Science and Traditional Engineering and Technology Programs - How to Improve Operational Excellence

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Abstract

This paper focuses on the application of Data Science to improving operational excellence (OE) for the process industries. By operational excellence, we mean the ability of a processing facility to operate safely, reliably and in an environmentally friendly manner while producing quality products, minimizing operating costs, and adapting to changing market conditions. Improving OE requires collaboration among professionals from different technical backgrounds. In addition, it involves the analysis of large amounts of data to help make intelligent business decisions. Recent advances in data science, big data analytics, and machine learning could help in that regard. For instance, such techniques can help improve process safety, predict equipment failure, provide better data visualization, manage alarms and abnormal operating conditions, develop inferential models, improve performance of automation strategies and real-time optimization, and help make decisions in planning long term operations. The paper provides an overview of various techniques that have been used in the process industries to improve OE and suggests curricular enhancements to traditional engineering and technology programs to educate engineers in data science, big data analytics, and machine learning.

1. Introduction

We all are familiar with the statement: “In God we trust, everybody else bring data!” This is especially true in engineering where almost all decisions are data driven. Engineers pride themselves in using large amounts of data to analyze, design, construct, maintain and optimize processes and systems. Talking about the manufacturing sector for instance, viable and profitable operations depend on what is termed as “operational excellence.” In other words, process operations must take place while a number of objectives and constraints are met. First, processes must operate safely, reliably, and in an environmentally friendly manner. Once these three objectives are met, then profitability should be of concern. In other words, products must meet certain quality specifications, operational costs must be minimized, and the whole operation must be agile and responsive to the ever-changing business conditions. Of course, excellent record keeping is also necessary.

With the advent of computer technology and availability of inexpensive storage space, large amounts of operational data are being captured and stored in large databases. Initially, such data were used for record keeping and accounting. With computers becoming faster and more readily available, engineers started using such data to design, build, maintain, and optimize processes and systems to drive "operational excellence."

In the next section, a number of example areas are presented where improvements are achieved by using large data amounts of data.

2. Data Based Operational Excellence Improvement Opportunities

This section outlines just a few areas where improvement in operational excellence can be achieved by using large amounts of data. It is not an all-inclusive list but hopefully underscores the need for mastering data analysis techniques.

A. Environmental Applications

Whether it is called global warming or climate change, the bottom line is that human activity is negatively affecting the environment [1]. To measure the impact of process operations on the environment and meet established rules and regulations for emissions, a number of hardware-based measuring/analyzing technologies have been developed and implemented [2]. In many cases, utilization of such technologies comes at high cost while reliability is questionable.

Engineers have attempted to develop alternative, lower cost, mathematical models to predict operations emissions, for instance NOx emissions from olefins furnaces [3]. This task requires the use and analysis of large amounts of data. Data analysis techniques such as principal component analysis [4] and neural networks [3] have been used in most of the cases.

B. Equipment Reliability and Predictive Maintenance

Operational excellence requires continuous and uninterrupted operations with minimal unscheduled downtime. To achieve this objective, process equipment must operate reliably, which requires proper maintenance.

Instead of preventive maintenance, which takes place at specified time internals, predictive maintenance is based on the ability to predict the state of equipment and take preventive actions when it is required rather than at fixed time intervals. This leads to better equipment utilization and lower maintenance costs. However, it requires continuous monitoring and analysis of operational data.

C. Control Loop Performance Monitoring

To achieve product quality and drive towards low cost operations, automation is being used extensively in the process industries. Automation techniques range from simple feedback PID based control loops [5] to highly sophisticated model predictive control technologies and real-time optimization [6].

Key to the success of such technologies is the use of large amounts of data. Whether it is the development of a process model for controller design, a soft sensor in place of a high-cost analyzer or the continuous monitoring of the performance of the automation strategies, data are being collected and analyzed [7].

D. Process Monitoring

Inspite of the use of highly advanced automation technologies, humans monitor and supervise process operations. Process monitoring requires trending of many process variables in a way that allows process technicians to quickly draw conclusions about the state of the process. Data visualization is thus very important for this task [8].

E. Process Alarm Management

In the unforeseen event of an abnormal situation, a large number of alarms may be activated. Depending on the situation, a “flood” of alarms may occur. In such high stress cases, it is difficult for human operators to quickly assess which are the most critical alarms, decide about and take corrective actions. Could then data analysis techniques be used to extract and present to the operators the most essential information and suggest corrective actions? Instead of monitoring several variables, can data analysis techniques be used to combine them into a reduced set of “new” and richer in information content variables, and thus avoid a “flood” of alarms? Can also a number of process variables be monitored to deduce whether an abnormal situation is being approached, and thus pre-emptively warn human operators? Can data analysis techniques help in such cases?

3. Engineering and Data Science

Based on the previous section, engineers must use data to address important engineering challenges. There are many applications to prove that they have done so. For instance, data analysis techniques such as principal component analysis and/or neural networks have been used in the past to develop soft sensors [4]. However, do engineering curricula properly educate future engineers to further take advantage of the ever-increasing amounts of available data? Do engineers learn the latest in data science, big data analytics, and machine learning to be more efficient and productive in their area of specialization? Or should only data scientists, primarily computer science and math graduates, be concerned with data analytics?

It can be argued that traditional engineering curricula do not provide a strong foundation in data analytics. Many engineers have developed data analytics skills as part of their long-learning process through on the job training or advanced degrees. However, the largest impact will be achieved if undergraduate engineering programs also provide a good foundation in data science and machine learning. It can also be argued that because of the need for domain specific knowledge, it is preferable to educate engineers in the use of data analysis techniques rather than data scientists be used as engineers. Of course, in practice, there should be collaboration between engineers and data scientists if such an opportunity exists.

What should then be taught requires careful consideration given the fact that many programs have a constraint on the maximum allowable number of credit hours. It is suggested that engineering curricula include more than an introductory course to programming. In addition, a course in data analytics is necessary to introduce students to various algorithms and analysis techniques. Potentially, an introductory course in data visualization could be included.

Such a group of three to four courses could be offered in the form of a certificate for professionals and become a stepping-stone towards an advanced degree in data analytics?

4. Conclusion

By considering the case of operational excellence for manufacturing processes, a number of areas were pointed out where benefits can be drawn and enhancements be achieved by using large amount for easily available process data. For engineers to take advantage of recent advances in data science, enhancements to traditional curricula must be introduced. It is suggested that courses in programming, data analytics and data visualization will help achieve this goal.

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Biographical Information

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