A Cloud Based Solution with IT Convergence for Eliminating Manufacturing Wastes

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Abstract. Identifying the key causes of inefficiency in a manufacturing plant is an important step towards eliminating process bottlenecks. Networked sensors, embedded systems and information technology solutions play a crucial role in measuring critical parameters and discovering causal relationships using data mining The challenge is how to rapidly interconnect disparate and 'multiple generations' of sensors and embedded systems and reliably feed the data to an enterprise cloud for real time analysis. The convergence of industry best practices, manufacturing technology, data capture, data mining and the cloud platform is needed to reduce manufacturing inefficiency. This paper examines how cloud computing could enable rapid implementation of industry best practices and mine the data for eliminating inefficiencies. We describe the challenges and solutions for monitoring and controlling the manufacturing process and data mining techniques for processing operational data.

Keywords: Cloud services, IT-based Convergence Technology and Service, Manufacturing

1 Introduction

Information technology (IT) convergence in manufacturing involves the fusion of various advanced technologies like internet, networks, sophisticated equipment, sensor data, software etc., for various applications. IT convergence leads to higher performance, quick results and business benefits. Imagine an assembly process line that has a few hundred steps which are needed to be completed precisely and in the correct sequence. These exact steps transform the raw material to finished goods. The Plant Management needs to monitor Key Business Performance Indicators such as the quantity and quality of goods produced and the resources needed to produce and deliver them to the customers [4].

In manufacturing, a large amount of data is needed to ensure product integrity, maintain traceability for applicable legal requirements, accounting, supply-chain

management and executive decision making. In order to meet these objectives, a large amount of data from multiple sources needs to be collected and analyzed. This is a non-trivial task since the data sources are varied and heterogeneous and there is no communication link between most of the data sources.

The objective of this research is to design and develop a cloud based data mining solution to monitor and improve the efficiency of the manufacturing. Specifically, we develop the architecture of such a system with interoperable components, which can scale up and facilitate the integration of new components as and when needed. The contribution of this research is the development of a system that the operations managers and the executives of a manufacturing plant can use for decision making and long term planning and setting policies.

2 Background

At every step of the manufacturing process PLCs (programmable logic controller machines), sensors, tools and various devices have the ability log data. This data can be about man, method, machine, material, measures, and environment. It can comprise of process or product attributes. Each PLC, device, sensor or tool communicates using one of the various protocols- RS232, USB, TCP/IP, CAN, etc. In a practical scenario the devices maybe compliant with the latest standards or they may be several generations old. The devices in many situations are not replaced for as long as they can be made to work. An old PLC may not have the network support that the latest PLCs may have. At the application layer the devices may support various standards. The challenges are to gather real-time data from the devices quickly, reliably and in a cost effective manner.

The manufacturing targets and the current number of units produced, downtime, waste and other key-process-indicators are invariably monitored in real-time on the shop floor. This helps the personnel to see a live score-card and provides valuable real-time feedback. To reliably process this data, significant infrastructure costs may be incurred. Additionally, teams of trained professionals (in-house or outsourced) are needed to maintain the IT infrastructure required to store and process this data.

3 Proposed Approach

A common approach to connect the various devices used in manufacturing is to write custom software. However we lose time and money in design, development and testing. Later on, it may take longer to implement and difficult to maintain. To overcome this hurdle a framework such as KEPServerEX [2], could be used. It supports all open standards and provides Application Programmable Interface (API) for development and can plugin proprietary drivers where needed to communicate with devices. Using this framework data can be captured from the devices and used for all kinds of software applications, real-time monitoring and decision support. In this research, we propose a cloud based system that uses the KEPServerEx framework as the backdrop for effectively managing the manufacturing processes within an

organization. This system includes various components for data collection and monitoring through appropriate sensor networks, housing the data in appropriate data marts, analyzing the data using data mining techniques, and providing tools for decision making. The architecture of the proposed system is shown in Figure **1.** The components of the proposed system are briefly described below.

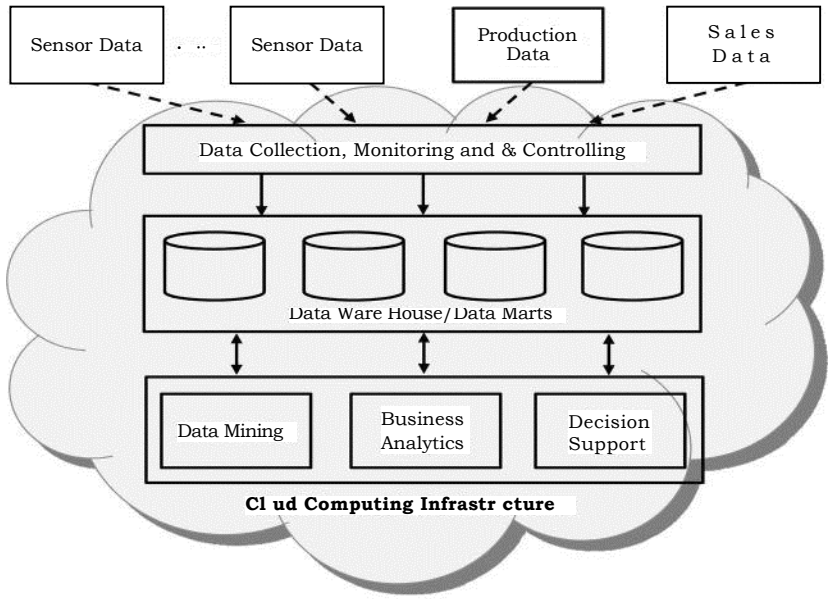

Fig. 1. Cloud Computing Infrastructure for Manufacturing Application

Data Collection, Monitoring and Controlling

Raw Data from various sensors in the manufacturing process is captured in real-time and displayed. The Process statistics are monitored and control charts are plotted in real-time [3]. There may be random variances and noise in the data captured. More critical is the steady non-random shift in parameter values. When the real-time values indicate that a process is going out of the control limits the cause has to be identified. Depending on the setup, a script can be created for most common errors. This can be used to make the process self-healing or can be brought back under control with a minimum impact to production. A lot of lessons are drawn from past experiences. Failure Models and their Effects are modeled. A risk priority number (RPN) can be assigned for each. RPN is calculated as follows:

RPN= Severity x Occurrence x Detectability.

This gives us what can go wrong based on the past experiences and what can be done to correct or prevent it. However, based on the data captured we can identify data patterns before and during a failure. We can perform knowledge-discovery in data. The first step towards this is regression analysis and data-mining.

Data Mining

Data mining of process data enables manufacturing organizations to identify opportunities for improvement and eliminating losses **[1].** This is done using various approaches such as Neural Networks, Association Rules, Cluster Analysis,

Classification and Regression Trees, Feature Selection, General Optimization, Kohonen Networks (SOFM), Logistic Regression and Generalized Linear Models, MARSplines, Naïve Bayesian Classifiers, Optimal Binning, Partial Least Squares, Random Forests, Response Optimization, Root Cause Analysis, Support Vector Machines. Predictive data mining is a data mining approach with the goal to identify one or more statistical model that can be used to predict some scenario of interest. Data mining and analysis play a vital role in condition based maintenance (CBM).

Business Analytics

As the financial credit score is used to determine the credit worthiness of an individual, the data mining algorithms described above are used to analyze historical data and create predictive models. These models could help determine risks in the manufacturing process, opportunities for improvements and could also help predict the quality issues likely to occur with the current setup. Recommendations from these predictive models could help: a) determine effective placement of the equipment, b) determine effective maintenance schedules to prevent downtime, increase equipment effectiveness, c) eliminate or replace error prone materials, d) eliminate or change error prone steps on the assembly line, e) improve safety, f) improve quality and compliance, g) improve return on investment, and h) meet target business objectives.

Cloud Computing Infrastructure

The data captured from networked sensors needs to be stored securely [5]. The transactional data is analyzed and the current state of the operations is accurately reported. This is important for business if it needs to determine the current ROI. Cloud computing offers a flexible approach in which the organizations can choose to have software as a service or platform as a service. The platform offers flexibility with regards to computational requirements, which may increase as the organization grows. This can be effectively handled on the cloud platform. Also the organization can only pay for the amount of service/resources utilized. The service provider maintains and manages the infrastructure and keeps it up to date. The software itself can be built and regularly update based on the industry best practices. The Data is stored and managed reliably on the "Cloud".

Decision Support

A clear global direction enables all manufacturing units to follow a unified architecture and encourages interoperability. This makes it easier to have a reliable overall picture of the enterprise using a cloud computing infrastructure that is well connected to the individual manufacturing units. In terms of short term decisions, it is important that the areas of improvement in the manufacturing process are identified, documented and prioritized. This will enable the organization set an agenda for the next phase of development. Documenting the current state enables an objective analysis for next phase. The first step is to start capturing the parametric data. With a clear global strategy it is easy to standardize the data capture and storage. The data captured using the various devices, PLCs and sensors are stored in the cloud.

In terms of long term decisions, data mining tools and techniques help identify causal relationships between the inputs and the undesirable events. Trends observed help direct preventive measures thereby avoiding or minimizing losses. RapidMiner,

Monte Carlo Machine Learning, Oracle Data Mining, Microsoft's SQL Server, and SATISTICA Data mining Software are some of the tools used for data mining in conjunction with the convergent IT infrastructure that captures, stores, and secures data from diverse inputs. For successfully realizing the benefits and eliminating the wastes in manufacturing data integrity plays a key role. If the data obtained is unreliable due to technical, process or human factors it will cause the algorithms to deliver erroneous results. It is important that the data integrity is maintained by preventing the bad data from being entered and validating data quality at each step.

4 Conclusion

Capturing data at each step in the manufacturing process enables us to provide real-time feedback to the plant. This helps the plant to keep track of production, ROI and in-efficiencies. Data mining algorithms help identify opportunities for improvement. While implementing such solutions can take a lot of time, a cloud based software as a service platform provides the latest solutions with reduced costs. We have described how cloud computing along with the reusable technological framework enables rapid deployment of industry best practices to 'mine data' for eliminating manufacturing inefficiency. The challenge of interconnecting devices to the enterprise wide solution can be overcome by using an intelligent cloud computing infrastructure that facilitates easy communication and data sharing using relevant protocols.

Acknowledgement

The work of the third author has been partly supported by Sogang Business School's World Class University Program (R31-20002) funded by Korea Research Foundation, and the Sogang University Research Grant of 2011.

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