The Acumence Manufacturing Business Intelligence Solution is a comprehensive business intelligence solution that supports real-time decision-making in high-volume manufacturing enterprises. It is uniquely architected for the real-time information technology needs and constantly changing operating environment of today’s manufacturers, so that operations and supply chain performance can be easily monitored, measured, and analyzed. Problems are detected in real time, through a solution that is easily deployed and maintained throughout the life of the operation. Acumence has eliminated the latency and resolution issues of traditional BI solutions by creating an environment where all data are available in full-resolution for real-time for analysis.

This white paper describes the technology behind the Acumence Manufacturing Business Intelligence Solution and demonstrates the value that a comprehensive well-architected solution for EMI has over traditional database technologies.
Manufacturers today are faced with making extremely complicated decisions in real-time, on a daily basis, with limited information.

Introduction

Consider the implications of accepting an order from a high-volume retailer, with a short turn-around time, at a negotiated price and slim profit margin. In addition to insuring raw material supply and scheduling production, manufacturers must understand the order's impact on operations. This requires detailed knowledge of changeover times, line efficiencies, availability of plants, lines, and assets, and a variety of other details that require sophisticated analyses to make optimal decisions for the enterprise. The need for more comprehensive manufacturing intelligence is driven by a variety of factors.

Product Proliferation — the raw number of products manufactured in a plant or on a line has increased dramatically in recent years causing shorter production runs, more changeovers, and more frequent modifications to plant machinery and equipment. What are the real manufacturing costs of each product? How long does it take to ramp-up production of a new product? What is the impact on the operation?

Supply Chain Responsiveness — companies who respond quickly to demand operate with smaller production runs, and lower supply chain inventory which leads to more frequent changeovers and ultimately, lower efficiencies in the plant. What is the optimal tradeoff between supply costs and perfect demand response?

Margin Optimization — companies must manage their product mix and promotional campaigns in a way that maximizes the manufacture of high-margin products, while minimizing products with low margin contribution. Which products generate the most profit and why?

Operational Excellence — manufacturers today strive for lower costs and higher operating efficiencies and are utilizing lean, six sigma, and other continuous improvement methodologies to achieve world class performance. Where are the bottlenecks and losses in a plant? Where can improvements and capital expenditures be used to achieve the greatest efficiency?

Change — the problems of today are not necessarily the problems of tomorrow, and as a result manufacturing operations are constantly changing. Manufacturers need intelligence solutions that easily adapt to the changing operation. How will the system adapt to an acquisition, divestiture, expansion, or new production line? Is an extensive budget and large group of experts needed to maintain the system?
Traditional Business Intelligence

There is a great divide between the traditional business intelligence systems of today and the real-time applications essential to efficient plant operations. Business intelligence systems have traditionally been applied to the vast stores of transactional data that a company creates, such as sales order, cost, and other financial data. Traditional applications perform batch loading of summarized data from ERP systems into a data warehouse on a nightly or weekly basis to facilitate reporting.

Manufacturing operations, however, cannot accept the latency of traditional business intelligence applications. Manufacturing business intelligence needs to be real-time in order to react, analyze, and respond.

Imagine a ship’s captain navigating treacherous waters using a report displaying the average location of the ship each hour of the previous day.

Manufacturing business intelligence must have sufficient resolution, not summarized, and with zero-latency in execution or transmission in order to provide a comprehensive view of the manufacturing operation right now, so that operations management can achieve company objectives.

Imagine the captain of a ship who wakes up in the morning to a report displaying the average location of the ship during the previous day.

However, traditional BI applications have proven the value of OLAP Cubes, drill-down reporting, and a variety of valuable dashboard, reporting, and analysis tools that have simplified the delivery of business intelligence throughout the organization. By identifying the best of traditional business intelligence systems and real-time manufacturing applications, one can imagine an operational intelligence solution that provides the real-time, high resolution data native to manufacturing operations within a business intelligence framework that delivers operational intelligence throughout the organization.

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Manufacturing Business Intelligence

Enterprise Manufacturing Intelligence (EMI) solutions provide manufacturers with an aggregated, contextual view of manufacturing data that can be used to monitor and analyze the operation in a variety of ways, supporting the real-time decision making needs of the organization. EMI solutions must provide manufacturers with a solid framework for capturing, ordering, and analyzing this data in order to meet these demands. The EMI solution of the future must provide manufacturers with the ability to:

- Aggregate and correlate real-time and historical operational data in full resolution, into a structure that provides a single, comprehensive, source of operational data.
- Create and manage the custom metrics (KPIs) that operations management is developing to measure performance such as perfect order rates, supply chain costs, OEE, production efficiency, scrap rate, and customized metrics for every level of the organization that provide real-time measures of company objectives as they change over time.
- Monitor and analyze operations in real-time, with detailed up-to-the minute information that combines real-time and historical data into a single environment, accessible across the enterprise, in full resolution, such as production totals, efficiency data, line performance and scrap.
- Detect and act upon changes in operational performance, in real-time, with tools for analyzing problems as they arise;
- Report results within each plant, and across multiple plants, in order to benchmark performance and measure progress towards results over time;
- Audit and correct operational data with a complete audit trail;
- Easily deploy and maintain the solution with minimal impact to the operations or IT organizations, and quickly adapted to manufacturing operations as they change.
Acumence Manufacturing Business Intelligence Solution

The Acumence Manufacturing Business Intelligence solution is a highly configurable application that allows manufacturers in the CPG, packaging, life sciences, and other high-volume manufacturing operations to accurately monitor, measure, track, and analyze the operation in order to achieve optimal levels of Operational Excellence — in real-time, and utilizing full resolution data.

The software is built on a comprehensive architecture that mirrors the manufacturing enterprise. This technology is the foundation and basis of the Acumence Plant Server, and is comprised of five key elements:

- **Data Model** — a comprehensive hierarchical model of plant systems including equipment, personnel, and production operations.

- **Data Store** — a lossless, high-resolution, real-time, compressed, distributed, enterprise, historical data store capable of aggregating and organizing all plant activity into a single database.

- **Data Transformation & Loading** — an SOA interface supporting configurable automated transformation and loading of events and production activity into the Data Model/Data Store.

- **Analytics & Metrics** — a layer of real-time execution procedures in the plant server that performs custom calculations, metrics, alerting, and business logic.

- **Data Retrieval** — a high-performance retrieval engine that supports 2-dimensional SQL, multi-dimensional OLAP data, and real-time streaming data to support live dashboard presentations within the portal.
Data Model and Data Model Management

One of the most important aspects of a manufacturing business intelligence solution is the data model. A data model can be as simple as a time-series database of real-time values similar to a plant historian, or as complex as a sophisticated model that mirrors the manufacturing operation. The value of a sophisticated manufacturing intelligence solution is in a data model that can accurately represent the operation, transforming real-time data into a valuable operational intelligence.

The Acumence solution is based upon a robust, comprehensive data model that follows the ISA95 specification. This type of data model captures manufacturing data into a data structure that mirrors the manufacturing operation, providing the data consumer with the most intuitive experience for dashboards, reporting, and analysis. The Acumence data model is made up of equipment model objects, production model objects, and a variety of general enterprise objects. The following is an abridged categorization of essential portions of our data model (see figure below).

The Acumence data model has been optimized to work with high-volume manufacturing of nonserialized discrete products such as aluminum beverage cans, glass bottles, packaged consumer goods, food, beverage, pharmaceutical, and similar products.

These nonserialized products are generally the result of a small number of raw materials processed through a series of discrete operations (filling, capping, labeling, forming, and packaging). Speeds are measured in units per minute. In a nonserialized manufacturing environment, all activity is correlated using time as the unifying variable.

In contrast, serialized manufacturing operations produce unique, serialized products such as automobiles, computers, and complex assemblies. Data models used in serialized manufacturing operations are typically keyed off of the unique serialized ID for each particular part. Speeds are usually measured in minutes per unit.

When performance is important, and products are not serialized, a nonserialized data model is preferred. Performance will be severely degraded and reporting will be substantially more difficult if a serialized data model is chosen for a high-volume nonserialized manufacturing operation.

Acumence Data Model — Key Concepts
Data Store

All plant information is stored in high resolution in a single database. Information is not stored as a time series signal like most historians, but rather, the data is transformed first by converting each captured value into a representative unit within context of the data model, and then stored in an easily retrievable format in full resolution. A large amount of data (typically the most recent 72 hours) is summarized in real-time and cached into memory for immediate retrieval.

Every data change is stored in the data store, including OPC events. As data changes are captured, dependencies such as calculated values and metrics based upon the data value are automatically updated as well. The Acumence data store also supports editing, deleting, or appending of data in the store. When any change is made to data in the data store, all dependencies are automatically updated and propagated throughout the system.

The data store is a lossless, high-resolution, real-time, compressed, enterprise historical database.

Acumence utilizes off-the-shelf relational database technology for long-term storage. All information is compressed before storing it into the database. There are no stored procedures or custom code running in the database. Only tables and indexes are utilized on top of standard ANSI SQL, resulting in a highly efficient data store, with high performance dashboards, reporting and analysis tools.

Loading data into the data store in real-time is a network intensive operation and typically necessitates a server at each plant because of the high latency, low capacity and low reliability of enterprise wide area networks. Enterprise aggregation and analysis is performed through an enterprise analysis server. Using this server, data from multiple plants can be cross analyzed and an enterprise can be modeled and analyzed as a whole rather than as a collection of plants.

Many custom systems used in manufacturing utilize both transactional databases (e.g. RDBMS) and time-series databases (i.e. Historians) to obtain the benefits of a transactional database yet achieve decoupled speed when executing queries on large amounts of historical or time series data. A transactional database is a general purpose disk based storage structure that is very efficient at storing and retrieving large amounts of data. Transactional databases create transaction logs, archive logs, and are generally understood to represent products like Microsoft SQL Server, Oracle, and MySQL. A time-series database is typically a proprietary disk-based storage structure optimized to capture time-series data in real-time utilizing compression and other means to achieve high-performance capture and retrieval of the data.

The Acumence Data Store utilizes a single transactional database coupled with a memory resident set of data transformation & loading (DTL), analysis, and calculation functions that achieve superior levels of performance while maintaining the integrity of a single data store and single source of data retrieval. Transactional databases by themselves are inappropriate as a real-time data store. However, by performing all DTL functionality in memory, and archiving into the historical data store on a periodic basis, the Acumence data store achieves superior performance while achieving all the benefits of an off-the-shelf transactional database like MS SQL Server, Oracle, or MySQL.

Data Transformation & Loading

Once a data model exists and the high resolution real-time highly compressed data store exists, data needs to be loaded into the data store. Acumence has created a highly configurable automated transformation and loading system that is configured through the administration client in conjunction with the Data Model. A typical source of data is OPC, but data can also come from other sources as well, including calculations and metrics that occur automatically in real time.

Data can also be loaded manually through a manual input entry in the portal, through a custom script written in our plant floor middleware layer, or from a transaction against a set of XML based web service API's.

Data does not need to be loaded sequentially in time. This makes it possible to load time-series data at any time, compared to traditional historians or other historical time series databases that must be loaded synchronously in real-time. Acumence supports data transformation and loading from most third party OPC servers including those made by Kepware, Matrikon, Rockwell, Siemens, and others.

Analytics & Metrics

Manufacturers today manage the operation by using KPIs, or Metrics, that tie operational goals and objectives to real, measurable results. In order for a goal to impact individual performance, it must be specific, achievable, and measurable. It is also important to minimize any latency between behavior and Metric results — the metrics should be available in real-time in order for an individual to change behavior quickly.

Acumence uses the concepts of Measures and Metrics to produce a comprehensive understanding of system performance.

Measures

Measures are simple calculations or data manipulations that occur in real time during the DTL process to capture real-time manufacturing data in a format that is most useful. For example, machine discharge count is a typical measure that is captured from a PLC on the plant floor as an incrementing register — much like the odometer in your car. Acumence will convert each value into an incremental count before being stored in a database. Other measures might include temperatures, speeds, calculated scrap counts, or just about any other simple or complex combination of data that can be processed by the Calculation Engine.
Metrics

Metrics, on the other hand, are complex calculations that are applied over time, or over a broad number of machines, lines, or plants. Metrics are not calculated in real-time as the data is loaded, but are calculated as data is processed or retrieved from the system. Examples include Overall Equipment Effectiveness (OEE), production efficiency, scrap rate, and any number of simple or complex calculations applied over time or to a range of equipment.

Metrics Management

Any number of metrics can be created. Acumence does not predefine industry metrics such as OEE, MTBF, or quality measures such as scrap rate. The Acumence solution allows custom metrics to be entered that are calculated throughout the system. These metrics are used to calculate values for different historical periods. Some are calculated in real-time and held in memory and streamed to the client in real-time. Others are computed when a transaction request is directed at the data store. The important note here is that a single flexible non-hard coded calculation is used throughout the system to perform all calculations on the metric independent of the time interval being reviewed.

Alerts

As information flows into the real-time data store, being able to alert essential plant and enterprise personnel of abnormal operating conditions enables corrective actions to be triggered automatically and in real-time. Through the use of our calculation engine, any number of alerts can be configured to be triggered based upon any number of alert limits. The alerting engine is based upon the OPC Alarm and Event specification and can be linked to an OPC based alarm client.

Data Retrieval

There are a variety of methods for retrieving data from the data store. The Data Store is a multi-dimensional repository of time-series events and transactions in the plant organized around the Data Model. Understanding and retrieving data would be extremely difficult if proper retrieval systems were not available.

Real-Time Historical refers to the combination of current, real-time data with complex historical results through unified data retrieval methods.

Acumence has developed the concept of Real-Time-Historical retrieval of information. This concept recognizes the fact that real people need a combination of up-to-the-minute real-time information, combined with detailed historical data, on the same dashboard or report. As a result, Acumence has combined three types of retrieval into a single portal environment:

- Real-time Streaming, which supports real-time dashboard display through the portal.
- 2-Dimensional SQL to support presentation of data through tables and graphs.
- n-Dimensional OLAP Cube to support detailed analysis of data.

Each of the data retrieval methods is also available as a connector for third-party systems to access the same information.

Real-Time Streaming Data Retrieval

The first connector to the real-time data store is through a streaming connector via OPC, or Aculink. Streaming connectors are needed when up to the millisecond real-time is needed in client applications. Client applications use streaming protocols to register data points with a server. Once registered, any data changes to the referenced data point on the server are automatically pushed to the client application in real-time. This results in a paradigm in which all changed data is pushed to the client immediately. The client then uses the updated information to refresh the user interface immediately.

2-Dimensional SQL Data Retrieval

The second retrieval method is transactional requests that retrieve information about a historical time period resulting in a two dimensional result set. These requests are formatted in ANSI99-SQL and sent to a SQL engine through either an ADO.NET Driver or through a JDBC Driver. These requests reference a virtual table structure or views that have been built on top of the Acumence data store. When the views are queried, the SQL engine parses the SQL request, retrieves the information from the views in the data store, and joins the information together to form a single two dimension result set. By abstracting the data views from the actual database tables, Acumence can insure the integrity of integration efforts. It is important to note that because the retrieval is being performed against the data store, all of the information is real-time. This means that as soon as the OPC event is processed, the historical information is available via SQL. There are no secondary loadings necessary.

n-Dimensional OLAP Cube Data Retrieval

The third connector performs transactional requests that retrieve information about a historical time period and retrieve an n-dimensional result set. These requests are formatted in MDX and sent to the Acumence OLAP engine through an ADOMD.NET Driver. These requests reference a virtual cube structure that has been built on top of the data store, much like the virtual tables and views that are queried by SQL. When the cubes are queried, the OLAP engine parses the request, retrieves the information from the data store, and joins the information together to form an n dimension result set. By abstracting the data cubes, it is possible to enhance and modify the core data model without destroying the integrity of integration efforts. It is important to note that because the retrieval is being performed against the data store, all of the information is real-time. This means that as soon as the OPC event is processed, the historical information is available via SQL. There are no secondary loadings necessary.

Acumence OLAP Cube
Enterprise Reporting and Analysis

All data within the Plant Server is also available on an enterprise-wide basis through the Acumence Enterprise Server. The Enterprise Server adds an additional plant dimension to the already existing data, and provides the same real-time, 2-Dimensional and n-Dimensional reporting and analysis retrieval methods to the data.

This allows data to be made available to enterprise-level BI solutions such as SAP B/W, Cogos, or other commercial BI solutions through either direct query of the Acumence OLAP Cube, or ETL from the Acumence Enterprise Server into the corporate BI system.

Acumence Portal

In order to achieve a user experience that is rich, graphical, and highly responsive; Acumence has chosen to use client-side application technology rather than rely on HTML and DHTML which has traditionally caused deployment issues with previous versions of Microsoft technology. The Acumence solution was designed with .NET, enabling painless deployments. The client-side applications consist of the Administrator, Portal, and Dashboard Designer.

The Administrator and Portal applications are accessed either through a small shell application installed on the client user’s computer, or via Internet Explorer 5.5 or higher. These applications will always connect to an Acumence Plant Server when running.

The Portal Designer is a stand-alone application running on the client user’s computer. Although it may connect to the Acumence Plant Server, this is not necessary. The Portal Designer may be used in an offline mode as well, making it easy to develop dashboards, historical reporting, and analysis screens in an offline environment.

Client Shell

The shell application is a small, auto-updating application that automatically downloads new versions from the server when available. When the browser hits the plant server URL, or the shell application connects to the server, the client-side applications are downloaded and cached to the client. This download occurs each time a new version of the client-side application is loaded on the server.

Upon connection to the Plant Server, the shell application will check the security of user, and launch the applications that are allowed according to the security policy in force. Each application will then check for updates (new versions on the server), cache the updated application, and download all model, configuration and operating data into memory.

By intelligently controlling the caching and updating of client applications, data model, and historical data the user experience is very quick and loading time is minimal while maintaining zero cost of ownership.

Security

The Acumence administration and client portals utilize a typical security structure with local users and groups. Everything in the data model is accessed by permissions and all permissions are centrally configured in the administration client. The security system can operate stand alone, or connected into an Active Directory.
Administration Client

A centralized administration client is used to configure the entire system. In this administration client, the entire data model is designed and configured. This is also where the transformation and loading is configured. The administration client is multi-user enabled such that multiple users can be editing the data model without conflicts. Changes made through the administration client are cached until the changes are committed against the model. As soon as changes are committed against the model, the model is modified in real-time and the transformation and loading functions are modified without the need for the server to restart.

Portal

The Acumence portal is a rich smart client based technology application that combines the best of aspects of a real-time display application and a historical transactional business intelligence application. By linking animations to the data model, any real-time client applications can be developed. By using the historical analysis tools to retrieve information via the SQL connector or the OLAP connector, rich historical analysis applications can easily be deployed. Portal client applications are built using a designer application and connect directly into the data store.

Portals used in a factory environment should be deployed using push technology with intelligent execution on the client side to allow a very interactive real-time display. It is important that this be coupled with a comprehensive historical data retrieval engine as well. The combination of real-time and historical data in a browser based portal allows the server to push alerts to a client in real-time and then have the user of the portal be able to drill into the data that has caused the alert.

There are a variety of methods for displaying, analyzing, and reporting on Metrics (KPIs). The OLAP Cube as a data retrieval method acts as a basis for dissecting Metrics over time, across lines and equipment, and by shift, product, or customer. Analysis tools provide a drill-down capability that leads to faster diagnosis of problems, so that operations can quickly return to optimal productivity and achieve the stated goals.
The portal designer is used to build portal applications, which can be a combination of real-time display objects, historical forms, reports, and drill-down analysis objects. The designer uses intelligent objects that are designed to retrieve information from the Acumence data store very quickly and efficiently. Intelligent objects like the pareto object, count by hour object, and process variable trend chart, are easily linked to the historical data store through an intuitive assignment method, and real-time filtering criteria established at runtime within the portal.

The intelligent objects are tightly linked to the Acumence data model, which speeds implementation and design of portal dashboards and reports, and simplifies long-term maintenance and management of the system.

Localization

The Acumence solution was developed with localization in mind, and is easily implemented in most foreign languages. Currently, the system is installed and running in 11 different languages.

Summary

Achieving the highest levels of operational excellence in today's manufacturing environment requires massive amounts of operational data, in real-time, organized for high-performance visualization, reporting, and analysis. Combining the strengths of traditional business intelligence systems, with the best functionality, and performance of real-time plant applications has resulted in a sophisticated manufacturing business intelligence solution that provides operations with the intelligence they need to meet the growing demands on manufacturing, while achieving ever improving levels of operational excellence.