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Developing Integrated Performance Measurement System using Component Based Approach

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Abstract:
In an industrial context defined by more acute competition, performance measurement becomes a control tool. The Business Intelligence module of Manufacturing Execution System (MES) software achieves Performances analysis function. However, the implementation of performance indicators in information system is a difficult problem. Indeed, the enterprises need methods to specify and to install their Performance Measurement System (PMS). In this paper, we propose a methodology of performance indicators implementation. We use the UML language to develop PMS model and Component Based Programming for its implementation. This method facilitates Performances Measurement System design and implementation.
Keywords: Manufacturing Execution Systems, Business Intelligence, Performances Measurement Systems, Component Based Approach.

1 Introduction

Nowadays, the level of integration determines the effectiveness of modern technical systems. Application of the system engineering results in that systems become distributed, and consist of a number of physically or logically distributed components that constitute the system to reach the common goal. Communication between such components is a crucial issue.

The MES software allows efficient integration of computer control systems and achieves the coordination of all production resources. Performance Measurement function is provided by Business Intelligence (BI) module of Manufacturing Execution Systems MES [1]. It is based on the computer controller systems and allows: Data collection, performance indicators computation and scorecards display.

The development and the implementation of a Performance Measurement System (PMS) is a difficult problem. Indeed, to design and implement a PMS, we must properly model identities, attributes and operations of individual objects as well as the sequence of operations and data flow in a shop floor control system. What will allow, thereafter, the time follow-up of the key performance indicator (KPI). Therefore, in this paper, we present a PMS model and its implementation using Component Oriented Approach.

The main body of this article is organized as follows. In the next section, the MES software, that allows production control, is presented. Then, the design methods of integrated production system is presented and discussed. After then, proposed approach for specification and implementation of PMS is outlined. The article closes with a practical example and drawing a conclusion.

2 The manufacturing execution systems softwares

The rapid progress of computer technologies brings shop floor control functions into a new area. Many advanced functions have been introduced as the results of improving computing power. These functions include real time scheduling, networking, cell coordination and Performance analysis [2].

In this section, we will present the MES software and the functions they achieve. First, we are going to describe the Computer Integrated Manufacturing (CIM) pyramid. Then we will position the PMS in this pyramid. Finally we are going to present Business Intelligence module and its functions.

2.1 CIM Pyramid and Shop floor control

Since the functions of shop floor control have become more complex than before, several control architecture and models were proposed. One of the most famous models is NIST AMRF (National Institute of Standard and Technology / Advanced Manufacturing Research Facility) Proposed by National Bureau of Standards. The AMRF model is applying hierarchical control architecture; it is composed of five-level hierarchy: facility, shop, cell, workstation and Actuator/Sensor. Each level has its specific functions. The business functions such as; cost accounting, aggregate planning, are executed in the facility level. It is done generally by ERP software. Shop level is responsible for coordinating production tasks including resource allocation and task assignment. The tool used at this level is The Manufacturing Execution Systems MES. Cell level is subject to sequence similar parts in batch jobs and supervises supporting tasks such as material handling and transportation. The supervision is achieved, generally by SCADA software. A workstation level is responsible for monitoring the execution of production tasks. It consists of a robot, a fabrication station or a material storage buffer.

We seek interest in shop floor control functions provided by MES software's. We will then present the functions achieved by theses software's. Indeed, before the advent of the MES software, the Work Orders printed by the ERP software, were transmitted by hand to the shop floor manager. Based on shop floor state (breakdowns, delays), he directs the products lots rooting and allocates to each operator the tasks to achieve. The technical information on product is handed to all workstations by technical manager. For data collection, production sheets are elaborated and the workers are asked to fill them. These sheets allow to summaries the production, time, and defaults data. The raised data is thereafter recorded in a computer system. They allow maintaining a production history and achieve product tracking and performance indicators computation. This method has, until now, given satisfaction. However, the companies must be nowadays more reactive and effective.

Firstly the MES is supplied with Work Orders, then it sequences and times activities based on finished resources capacities, allocate resources and define what people, machines and tools should do. It also manages and distributes information on products, processes and designs. Then it gives the order to send materials to certain parts of the plant to begin a process. Finally it directs the flow of work in the plant based on planned and actual production activities, and monitors the progress of products units, batches or lots.

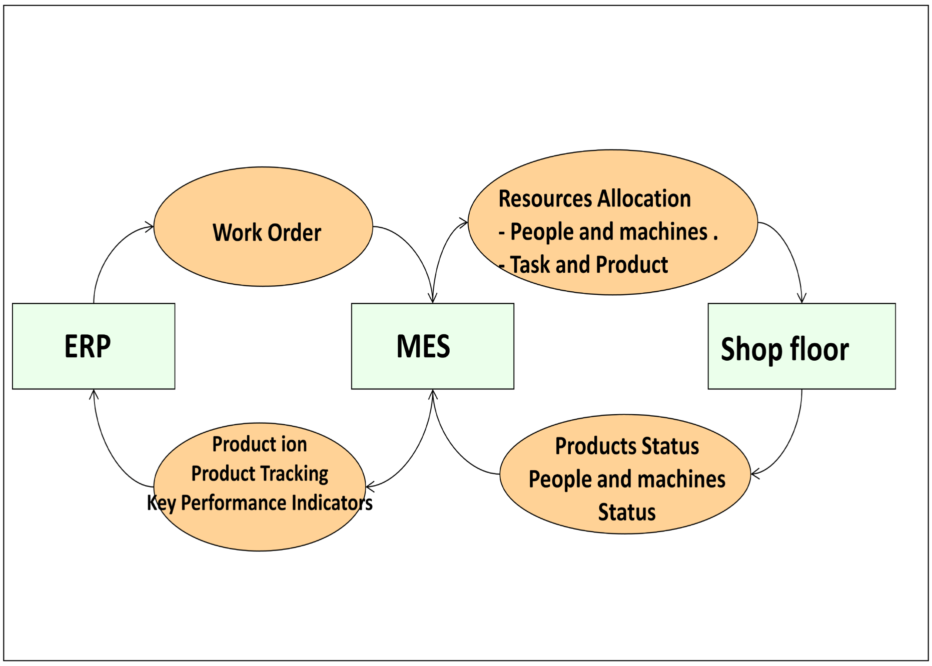

Figure 1: Information flow between MES and other systems

When the product is achieved, the MES collect data about products; people and machines work and track what they have done, to create a full history of the product. It gathers, also, certification statements of work and conditions. Then it records, tracks, analyzes product and process characteristics with engineering ideals and compares measured results in the plant with goals and metrics set by the corporation.

An MES Software is generally a production server that collects permanently the state of the available variables on device controllers and SCADA systems distributed in the shop and record this information in Database system. To achieve database management it must include a communication tool that allows automatic operation integration with external systems (ERP, GPAO).

To meet the needs of a variety of manufacturing environments, MESA identified 11 principal MES functions. Thus, if the MES functions set is theoretically invariable, the priority between them and the configuration can vary and be adapted according to the aims of the company. Among the solutions provided by software editors we mention : Wonderware MES 4.0 [3] and Mapex production manager v7 [4].

The integrated actual market solutions answer partly company needs and require a complete review of existing applications. The EAI (Enterprise Applications Integration) solution is an alternative to the integrated MES solutions for the Company [5].

2.2 Business Intelligence (BI) module of MES Software

The Manufacturing Execution Systems MES achieve performance Analysis function provided by Business Intelligence (BI) module. The PMS is based on the computer controller systems for:

1. The data collection (starting time, break times, completion time, products quality),
2. The computation of performance indicators and

3. The display of scorecards.

Bar-codes are used to identify Work Orders. Sensors linked to workstation controller are used for produced parts counting. The workers collect events occurred on machine keyboard. The information are collected by SCADA Software and recorded to relational data base. Data aggregation and indicators computation is assured by MES Software. The MES Software includes integrated Business Intelligence BI module used by all others MES modules to improve business decision making. Indeed, Business Intelligence BI must be able to provide production reporting, end-user query, dashboard/screen tools, data mining tools, and planning and modeling tools. It must provide the right information to the right person throughout the organization. A BI system is a data-driven DSS that primarily supports the querying of a historical database and the production of periodic summary reports [6].

The product data used by MES Software to generate KPI have high frequency traffic pattern. Also, the shop floor and company departments have their own applications that use and produce data. This generate data heterogeneity problem. It is necessary therefore to provide interfaces between the different databases, important memories size and achieve data codification.

We propose, then, to adopt structured approach for Performance Measurement System development. In the next paragraph, we will present the different methods of an integrated production control systems design.

3 The design of integrated production system

The integration of the information required by the co-operation of manufacturing applications has become a crucial issue for enterprises. However, ther is wide spectrum of information sources and the existing software components are heterogeneous. An integrated infrastructure that provides a set of services for information access and management, production resource control and monitoring interprocess communication must be developed. Based on well accepted standards this infrastructure will convert from closed proprietary systems towards interoperable and networked applications. Enterprise integration (EI), which emerged after the Computer Integrated Manufacturing (CIM) era, has been heavily discussed and investigated since the late 80s with the seminal work on the CIMOSA architecture [7]. Also, the component approach can be used to achieve the interoperability of computer control systems and to allow components reuse [8].

In this section, we will present integrated production systems and different methods used for its design. First, we are going to describe the method used for Computer Integrated Manufacturing System design. Then we will present the CIMOSA framework and Component Approach for Enterprise integration. Finally we are going to return to our problematic to redefine it.

3.1 The methods used for Computer Control System design

A design of an integrated production system is a big project that includes several jobs; programmers, automation engineer, mechanics. A design of shop floor controller is achieved through several steps: 1 Requirement analysis, 2 Existing System Analysis As Is, 3 System Specification, 4 Solutions Proposition and feasibility validation To Be, 5 Equipments installation, 6 Controller Implementation, 7 Operation and maintenance.

In the Requirement analysis step the requirements of the proposed system are collected by analyzing the user needs. This phase is concerned with establishing what the ideal system has to perform. However it does not determine how the software will be designed or built. Usually, the users are interviewed and the user requirements document is generated.

During the Specification, it is necessary to describe functionalities of equipments (production system) and the controller (information system). Thus, modeling methods are used. Business process modeling is the activity of representing a company processus, so that the current process may be analyzed and improved. BPM is typically performed by managers who are seeking to improve process efficiency and quality. It allows the construction of models of a determined part of an enterprise. The evolution of the complexity of information systems, the worry of optimization of software applications design drove the scientists to develop some modeling methods. The classic modeling methods describe the Information system and proceed to separate treatment of data and processes. The object-oriented methods are new approaches of development. It considers a system like a set of objects in interactions (every object achieves or undergoes some operations), examples of these methods (UML, OMT). The methods dedicated to distribute systems are those allowing the development of multi agents systems (with distributed execution objects).

The Implementation is a setting step, which consists of machines and control softwares choice, supervisory control interfaces programming and tests. Shop floor control must be integrated system. Interoperability requirement is difficult to achieve. Indeed, many companies selling industrial software tools and hardware, such as distributed control systems, SCADA (Supervisory Control And Data Acquisition) packages, programmable controllers, etc., provided external interfaces for interoperability but employed proprietary protocols requiring custom software development. Integration of applications meant substantial development effort to provide adapter layers so that applications could operate collaboratively and share data.

3.2 CIMOSA Framework for Enterprise Integration

The concept of abstract manufacturing services, which came up with the CIMOSA Framework for Enterprise Integration, is to provide the manufacturing processes with a set of abstract services supporting the execution of industrial operations by the resources. These services are system-wide, callable through an interface consisting of basic functions for starting or stopping an operations and independent of any resource implementation details. The actual dialogue with a specific resource occurs outside the application, within a manufacturing service provider accessible through this interface. The manufacturing application limits its role to the control of operations, and remains unaware of their physical implementation. Applications based on abstract manufacturing services can be easily configured and extended for a new manufacturing layout, as any technological detail is encapsulated within the manufacturing service provider.

The Integrating Infrastructure (IIS) as specified in the CIMOSA Formal Reference Base is made up of a set of distributed services, which allow generic system-wide functionalities such as the control of manufacturing processes, the administration and exchange of information, the scheduling and monitoring of resources, and the interfacing with human beings, machines and application programs.

Business Services (BS) provide services for controlling the manufacturing processes: they control the execution of Functional Operations by the different resources, following the procedural rules described in the functional model of the manufacturing processes. They allocate the resources and retrieve the necessary information in the information system.

Information Services (IS) manage system-wide the enterprise information (location, replication, access right, etc.) and provide a homogeneous interface for accessing the different data storage units such as databases and file systems.

Presentation Services (PS) provide a homogeneous interface to the various manufacturing resources (machines, humans and applications). They provide abstract Manufacturing Services to the Business Services, and control the execution of the corresponding Functional Operations by the resources.

3.3 Component Bsed Approach

In the same topic, component based approach is used to Enterprise Integration. Indeed, Component Programming have introduced revolutionized changes in software development, like engineering methods, component-based development, and assembling components based on their interface and semantics. This changes ease system interoperability and entreprise integration.

Software components are associated with their component infrastructure. A component infrastructure is the basic, underlying framework and facilities for component construction and component management. The different concerns involved in the realization of a software system can be divided into problem-specific and crosscutting ones. Problem-specific concerns relate to the main functionality that should be provided by the system. Distribution transparencies are typical examples of crosscutting concerns. Their realization imposes the need for additional functionality, which should be spread across the systems problem-specific abstractions. Any distribution transparency involves using middleware services that require a broker, which provides access transparency. Achieving transaction transparency amounts in using services that implement a distributed atomic commitment protocol. These services further require others that enable synchronization and persistence. The middleware provide some high-level services related to applications communication needs called Inter Process Communication, IPC. It is located upon the transport layer in the OSI model (layers 5, 6 and 7). The double mission of middleware interfacing is:

The client server process, that achieves Remote Process calls implementation and manage call and results return functions between applications.

The data translation, which defines data format and syntax, so that the transport layer can send this data across network.

3.4 Problematic definition

Several researchers have applied Object-oriented and Component-oriented concepts in implementing manufacturing execution systems MES. For instance, Yang [9].applied object-oriented programming (OOP) to develop a CIM system. In addition, a distributed automation and control system has been implemented in [10].For system integration a middleware CORBA were used. Another work was addressed on applying COP methodology to develop a controller, in robotic palletization area [11]. Although various works related to the modeling and implementation of shop floor controllers were presented, the implementation of PMS was not addressed by those researchers. Specially integration of PMS with other applications. Component approach can be used to support this issue. Basically, it focuses on:

Identifying objects, their related properties and building the relationships among objects,

Integration of the PMS within the control system (data collection and interoperability).

4 Proposed approach

As a first step, we propose to model the system by using UML language. We adopt the use cases diagram to elaborate the functional model of the system. The use cases identified are the different activities proposed by the ISA S95 standard [12]:

The product definitions and production resources management

The detailed production scheduling, production dispatching and execution.

The production data collection, production tracking and production performance analysis.

As far as we are considered, we deal with big interest with production data collection and performances analysis activities.

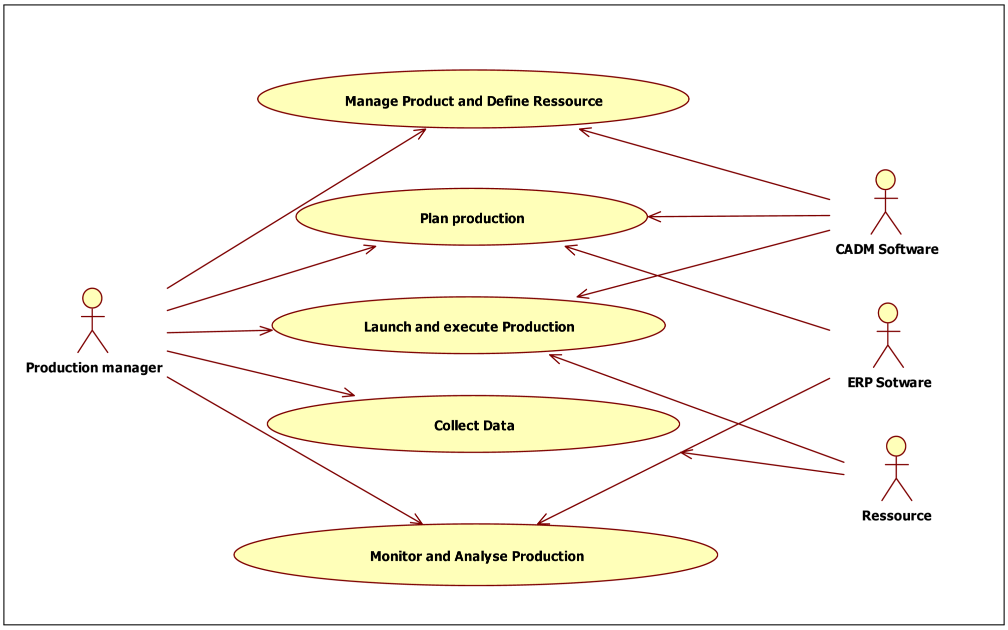

Figure 2: Tha use case diagram of Manufacturing Execution System

To describe the static view of the system, we must identify all its classes and objects, including physical and conceptual system entities. The products, processes, workers and other industrial entities are modeled in UML static view by class diagram. It shows the class attributes, and the relationships among the classes. A product routine is a set of operations that describe the methods used to manufacture a product. An operation is allocated to a resource. A work order WO is associated to a product. The data about WO operations are collected and recorded in a report.

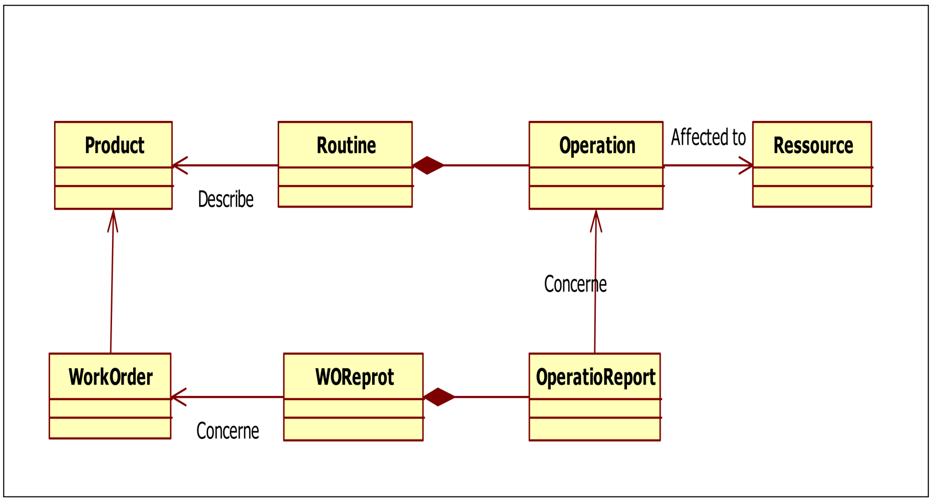

Figure 3: Tha Class diagram of Performance Measurement System

The script achieved by the BI module of MES software is as follow:
The ERP Software sends to MES Software the information about launched Work Order WO.
The MES Schedule the WO and launch its execution via the SCADA System to workstation.
During production process the SCADA System collects the data about each WO.
When the WO is finished, production information is feedback from SCADA toward MES

Software.

The MES Software transfers to the ERP WO reports, that computes and displays performance indicators.

As a second step, we propose to adopt a Component-oriented approach for PMS implementation. Indeed, it is necessary to elaborate an integrating infrastructure that allows an interoperability of the distributed system. We propose to adopt Enterprise Application Integration architecture (EAI), for Control system integration and PMS implementation. We propose, therefore, an integrating infrastructure based on computer standards, like XML format, that allows the different heterogeneous applications to communicate by messages sends and receipt. The Integration Platform regroups the components that support the interoperability. It provides both data centralization and communication services that allow tools to share data and communicate between themselves. In addition to communication services, the integration platform contains a user interface module and a runtime coordination that contribute to integrated operation.

5 Practical example

The proposed method is applied to the flexible machining cell in ENSAM. We will develop a PMS for its control. The PMS developed is the OEE Overall equipment effectiveness measures. There are three underlying metrics that provide understanding as to why and where the OEE gaps exist. These measurements are described below:

Availability: The portion of the OEE Metric represents the percentage of scheduled time that the operation is available to operate. Often referred to as Uptime.

Performance: The portion of the OEE Metric represents the speed at which the Work Center runs as a percentage of its designed speed.

Quality: The portion of the OEE Metric represents the Good Units produced as a percentage of the Total Units Started. Commonly referred to as First Pass Yield.

OEE is computed as follows: OEE = Availability x Performance x Quality.

To implement the PMS, we must integrate it within the control system. Indeed, it should collect the data, from the shop floor control and send the performance indicators to the business information system.

We will describe the OEE measures implementation. Firstly, we are going to describe the technical architecture of the system (data collection material). Then, we will present, the software architecture that allow system implementation (products data configuration, BI module deployment).

The Manufacturing system is organized around a Transport system which allows a routing of the work-pieces, placed upon work-piece carriers, toward a CNC milling machine. A jointed-arm robot is used to load and unload parts for CNC machine.

In the control architecture of the system, a SCADA software (CIROS Control) is installed in the top-level computer. An Ethernet network is connecting several machine controllers. The CNC machine is equipped with a DNC link based on RS-232 , the robot and Transport system with Ethernet extension. Profibus DP connect stopper boxes to the transport system controller.

The strategy of integration was to provide a common software infrastructure (Integration Platform) that would allow a wide variety of application tools to communicate and share data, while minimizing the specific development for each tool. The heart of the Integration platform is SCADA software CIROS Control. It is a real-time, object-oriented development environment.

The PMS must communicate with the SCADA software CIROS, it must also communicate with a MES software ICIM Production Manager.

Let us consider a work order sent by the ICIM Manager to the cell controller CIROS. The cell controller will select the production routine of the considered part from the Routine File

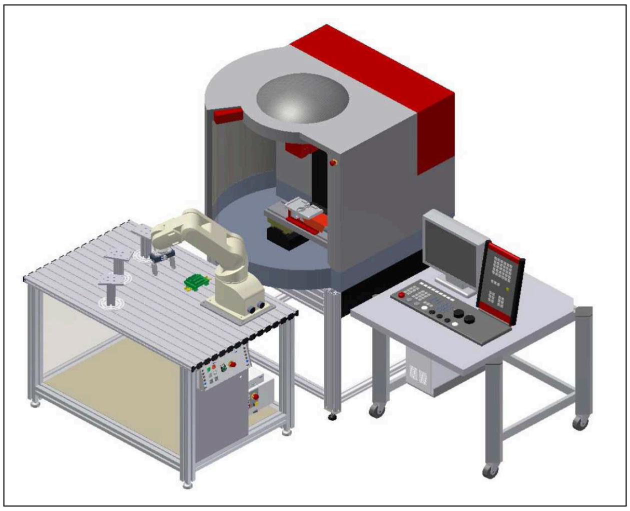

Figure 4: The ENSAM Machining Cell

database. It will check about the resources status. If all necessary resources are available, it will determine adequate material and start the tasks. To develop reports it is necessary, at first, to extend the ICIM Manager Data Base and add Report Tables. Then we must determine the necessary data site, on the ICIM Manager Data base tables. After then, we must establish computation formulas of the indicators to display. We must also, develop SQL queries to select the data from Data base tables. The reporting tools Crystal Reports allow reports development. It is necessary to connect at first to the ICIM Manager Data base through ODBC server, in order to reach all data that will be used in the reports. ICIM Manager provided XML files that allow the communication of the data to reporting tool.

6 Conclusions and Future Works

The use of Object and Component approach, proven industrial technology coupled with message oriented middleware considerably eased the process of application tool integration. it allowed a better flexibility of the PMS. Although the proposed model is focused on a CIM system in the educational environment, several concepts developed from this model still can be applied in the shop floor controller utilized in other environment.

As perspective, we will consider, in addition to interoperability problem, the possibility of KPI component reuse. To do this, we will explore different possibilities, for example, the use of UML Profile. Which means, applying stereotypes, tag definitions and constraints, to the Classes, Attributes and Operations, that we previously defined in our research and define specific profiles in Production Control area.

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