PROMME: A METHODOLOGY TO PRODUCTION MANAGEMENT IN DISTRIBUTED MANUFACTURING ENVIRONMENT

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Abstract. *The objective of this work is to present a methodology (PROMME) to production management. This methodology is a part of WebMachining system, which is based on Electronic-Manufacturing concept (Digital Manufacturing), especially a part of this concept: Telemanufacturing. The virtual company WebMachining contains three distributed manufacturing systems (FMC Graco/UnB, FMS SOCIESC and Lathe UFSC) which present the main hardware of the entire system. The methodology PROMME includes planning, programming and remote fabrication of parts. The remote fabrication works by using the web to control the three distributed manufacturing systems. The costumer uses the manufacturing services with the SOA (Service Oriented Application) of the WebMachining virtual Company by using the internet, to execute operations and necessarily processes to design and produce the parts with a high amount of efficiency and flexibility. The PROMME integrates the engineering and the production management by an ERP / CAP software written in Java language. The ERP / CAP will preview which of the three systems will produce the ordered part. This decision is based on different parameters that the three systems have. After the decision, CAP will create the production programming and scheduling. With this methodology will be possible to receive the costumers orders, to integrate the CAD, CAPP, CAM, CAP / ERP and finally to produce the part in one of the three systems. The description of the problem was made by using the methodologies IDEF (IDEF0 and IDEF1X) and UML. These methodologies are used to specify the modules and how they interact between themselves. This form of description gives a detailed look of the problem. The advantage of this work is to have a web based system that controls distributed systems no matter where they are located. The PROMME contains a new concept for production management and can be applied to any industry.*

Keywords*: Production management, telemanufacturing, distributed manufacturing systems, ERP / CAP, scheduling.*

1. INTRODUCTION

In a production system, when an objective is formulated, is necessary to formulate strategies to reach this objective, to organize necessary human and physical resources for the action, to direct the action of the human resources on the physical resources and to control this action for an eventual disturbances correction. In the scope of the production management, this process is realized by the function of Production Planning and Control (PPC).

According to Burbridge (1988), the objective of the PPC is to provide an adequate use of the resources, to produce specific products by using specific methods, to perform an approved sale plan.

The main objective of the PPC is to manage the productive process, transforming information of some sectors into production orders and purchase orders, to satisfy the costumers with quality products and services and the administrators with profits (Martins, 1993).

The study of the production planning and control systems (PPCS) is a very important subject in the production management. According to Corrêa and Gianesi (1996), the PPCS are the main part of the productive processes. The PPCS are systems that support the efficient management of the flow materials, the use of man power and equipment, the coordination of the internal activities with the suppliers and deliverers' activities, and communication/interface with the customers for its operational necessities. In the Vollman et al. (1997) research, the PPCS help the administrators in the function of decision making.

According to Maccarthy (2000), some of the main ones and more used PPCS are kanban, PBC (Period Batch Control), OPT (Optimized Production Technology), MRP (Material Requirements Planning), MRPII (Manufacturing Resources Planning) and PERT (Program Evaluation and Review Technique)/CPM (Critical Path Method). Because of this diversity, the choice of which PPCS is most adequate for diverse situations becomes crucial.

In a recent work, Corrêa et al. (2001) affirms that no PPCS can be considered the solution for all cases. According to him, to work with different logics to answer the different necessities, demand, many times, the integrated use of more than one PPCS.

In these circumstances, it was developed a methodology (PROMME – PROduction Management in Distributed Manufacturing Environment), for the production management of the virtual WebMachining Company, whose shop floor is composed by three distributed manufacturing systems (FMC Graco/UnB - Brasília/DF, FMS SOCIESC - Joinville/SC and Torno UFSC - Florianópolis/SC). The PROMME methodology includes the development of an ERP (evolution of the MRP-II) and the integration of this ERP with the engineering module (CAD/CAPP/CAM). In the engineering module, two part development environments are used: the WebMachining (Álvares, 2005) and the

Cybercut (Brown and Wright, 1998). The ERP is developed for web, thus allowing the customers to make its orders of parts in any place of Brazil, without have the equipment and softwares for the product development cycle, from project to fabrication. The PROMME also allows the employees of the company to connect remotely and perform its activities from any place. Figure 1 illustrates the remote access:

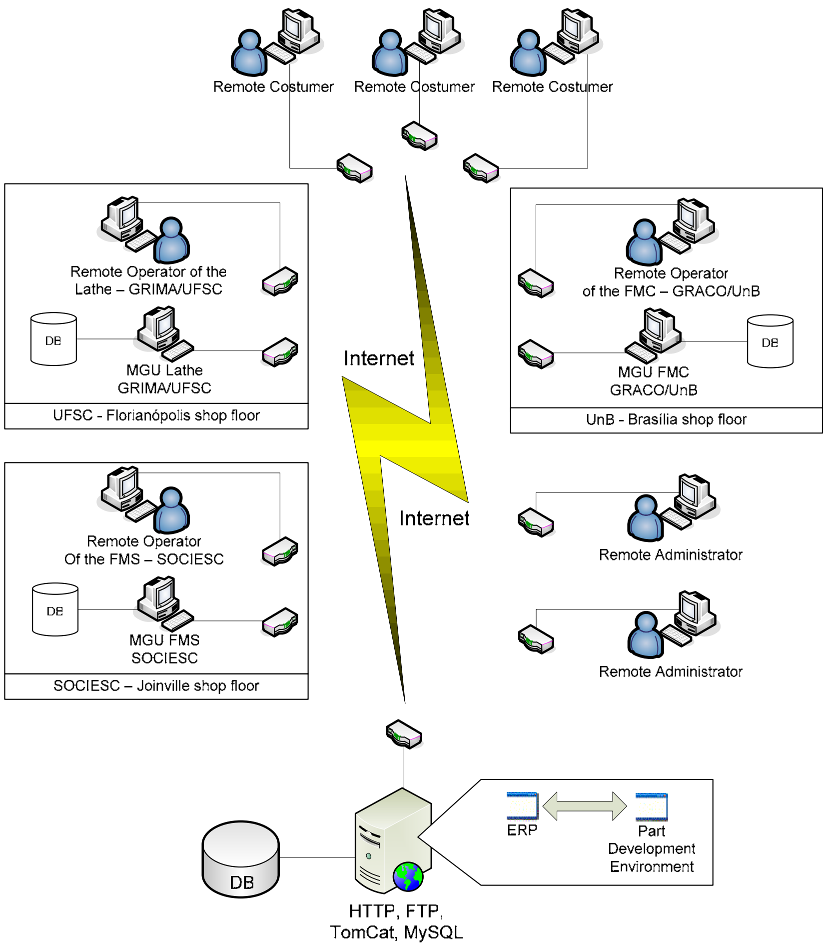

Figure 1: Remote accesses to the system

For the implementation, is used telemanufacturing, a part of the electronic-manufacturing concept. According to Malek et al (1998), a customer uses the manufacturing services via web (SOA – Service Oriented Application) to execute the operations and the necessary processes, projecting and producing, efficiently and with flexibility, the desired part, using computational tools for the development of the product life cycle.

2. OVERVIEW

2.1. ERP Systems

According to Zancul and Rozenfeld (1999), with the advance of the information technology the companies had started to use computational systems to support its activities. Generally, in each company, some systems had been developed to answer specific requirements of the diverse business units, plants, departments and offices. Thus, the information was divided between different systems.

The main problems of this fragmentation are the difficulty of getting the consolidated information and the inconsistency of stored redundant data in more than one system. Systems ERP (Enterprise Resource Planning) solve these problems by adding, in just one integrated system, functionalities that support the activities of the diverse companies business processes (Zancul and Rozenfeld, 1999).

Systems ERP are an evolution of MRP (Material Resource Planning) systems. MRP systems had appeared due to necessity of reduce the supply levels. These systems offered an integrated view of the goods, based on the available inventory and the periods of restocking. In 80’s years, the MRP evolved for MRP-II (Manufacturing Resource Planning). It was based, beyond the goods, in other essential resources to the production, such as man power, machines, etc.

According to Zancul and Rozenfeld (1999), the suppliers of the systems had developed more modules, integrated to the modules of manufacturing, but with target that exceeds the manufacturing limits, with the objective to extend the enclosing of the commercialized products. These new systems, capable to support the necessities of information for all enterprise, are called ERP systems.

Because of this evolution, today it is possible to include and to control all the company processes generating just one database, without the redundancies found in the previous systems, where MRP and financiers applications were not integrated between themselves.

The information arrives in clearer way, immediate and safe, providing a bigger control of the business, and mainly, of its vulnerable points: costs, fiscal control and supplies.

2.2. Electronic Manufacturing (e-Mfg)

The information technology, in special the communication nets technology and internet come opening a new domain for construction of futures manufacturing environments called by e-Mfg (electronic-Manufacturing). Work methods based in collaborative e-Work are used, in special for activities developed during the product development cycle in integrated and collaborative CAD/CAPP/CAM environments (Malek et al., 1998; Lee, 2003 & Nof, 2004).

E-Work (Electronic Work) was defined by the PRISM Center (Nof, 2004) as any activity productive that is collaborative, supported for computer and supported by communication in organizations highly distributed of robots and/or people or independent systems. In essence e-Work is composed by e-activities (electronic-activities), i.e., activities based and executed by the use of information technology.

According to Álvares (2005), this is a new paradigm for these based computational systems in globalize environment, making possible the development of activities using e-Work. E-Work allows the products developers, designers, have greater communication easiness, making possible the sharing and the collaborative project during the product development, as well as the teleoperation and monitoring of the manufacturing devices.

E-work is constituted of activities based and executed by the information technology, called electronic activities. These e-activities include v-Design (v-virtual), e-Business, e-Commerce, e-Manufacturing, v-Factories, v-Enterprises, e-Logistics, and similarly, intelligent robotics, intelligent transport, etc. All these e-activities are based on computational systems and communication technologies, and all require inherent contribution and interactions between machines, people and computers. E-work includes applications as tele-robotics, tele-manufacturing, teleoperation and remote services. Telework also is part of e-work in according to the general definition.

2.3. WebMachining Methodology

According to Álvares (2005), the methodology is conceived from the modeling paradigm based on synthesis for project features (addition of features for turning operations and subtraction of features for milling operations and hole). The methodology has the purpose to allow the integration of the collaborative project activities (CAD), process planning (CAPP) and manufacturing (CAM Planning and CAM execution). For this, it uses as reference the manufacturing features model defined by 224 Part and more specifically the features taxonomy of form for rotational parts defined by CAM-I (1986). The procedure is initiated in the collaborative modeling of a part using features in a context of remote manufacturing via Web, in a customer/server computational model.

Still in accordance with Álvares (2005), the originality of this architecture is associated with the methodological contribution for the development of telemanufacturing systems via internet (e-Mfg) from the conception (detailed collaborative project) of a product (part). It uses the approach of synthesis for project features until the manufacturing of the part, using the internet to connect the advanced technologies of manufacturing that are used. The process of development of collaborative product is initiated using the CAD interface agent (WebCADbyFeatures) oriented by features, working in a distributed and collaborative environment. With this, are generated: the part geometric and features model (detailed project); the process planning with alternatives and G code (WebCAPP). To follow, the teleoperation of machine-tool CNC is made (WebTurning).

The methodology can be applied for manufacturing of rotational parts, as well as for manufacturing of prismatic parts. The methodology and its implementation are concentrated in the collaborative modeling, process planning and manufacturing of symmetrical and anti-symmetrical rotational parts (Álvares, 2005).

2.4. CyberCut

CyberCut is a web-based design-to-fabrication system, developed by Brown and Wright (1998), consisting of three major components:

1. Computer-aided design software written in Java and embedded in a web page. This CAD software is based on the concept of destructive solid geometry (DSG); that is, by constraining the user to remove entities from a regularly shaped piece of milling stock, the downstream manufacturing process for the part is inherently incorporated into the design,

2. A computer-aided process planning system with access to a knowledge base containing the available tools and fixtures, and

3. An open-architecture machine tool controller that can receive the high-level design and planning information and carry out sensor-based machining on a Haas VF-1 machine tool.

According to Brown and Wright (1998), by providing access to the CyberCut CAD interface over the Internet, any engineer with a World Wide Web browser becomes a potential user of this on-line rapid prototyping tool. Once fully operational, a remote user will be able to download a CAD file in some specified universal exchange format to the CyberCut server, which will in turn execute the necessary process planning and generate the appropriate CNC code for milling. The part could then be manufactured and shipped to the designer. The engineer could have a fully functional prototype within a matter of days at a fraction of the cost of in-house manufacturing.

2.5. eMachineShop

eMachineShop (http://www.emachineshop.com) is a remote fabrication system that was used as example for the implementation of this project. It is a remarkable new service that gives you the power to make custom parts - whether it's one part for a racing bicycle or a million parts for a new product. eMachineShop takes the trouble out of getting custom parts by providing free design software you download, which gives you expert design feedback instantly, computes an exact price in seconds and lets you conveniently order via the web.

This is not an ERP system. eMachinineShop just controls the customers orders and the fabrication of the parts. This is the main difference between the two systems.

3. PROMME METHODOLOGY

The PROMME is a conceived methodology to make the production management in a distributed manufacturing environment. This methodology is applied to the virtual WebMachining Company, whose shop floor is formed by three distributed systems of production. For the management accomplishment, an ERP was developed. It makes possible the receiving of customers' orders, the administrative functions, the integration of CAD/CAPP/CAP/CAM and the part fabrication in one of the three manufacturing systems.

3.1. Distributed Shop Floor

The shop floor of the virtual WebMachining Company, as described previously, is formed by three distributed manufacturing systems: FMC Graco/UnB, FMS SOCIESC and Lathe UFSC. The UnB (Brasilia - DF) system is a FMC (Flexible Manufacturing Cell) (http://video.graco.unb.br) composed by a turning center, an industrial robot, an AGV, pallets of parts, laser micrometer, management unit (MGU) and an audio and video monitoring system, as it shows Fig. 2:

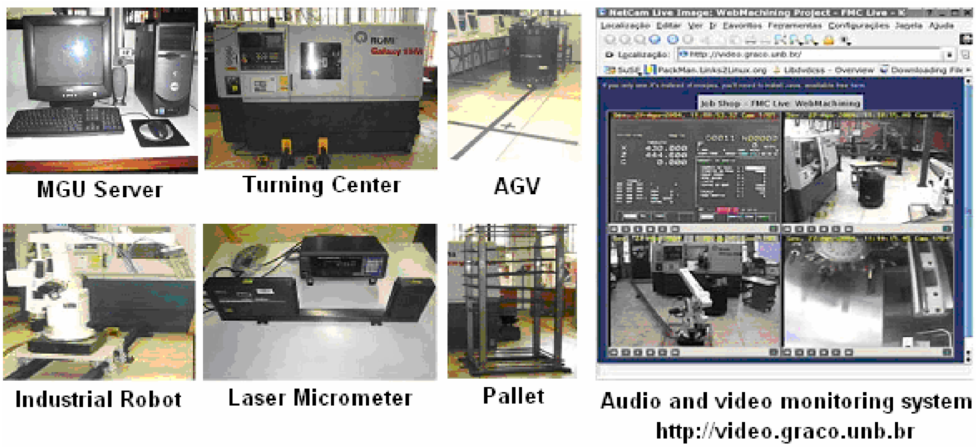

Figure 2: FMC GRACO/UnB (Teixeira, 2006) (http://www.graco.unb.br).

The SOCIESC system (Joinvile - SC), shown in Fig. 3, is a FMS (Flexible Manufacturing System) composed by a lathe CNC Mitsubishi Meldas 50, a machining center CNC Mitsubishi Meldas 500, an industrial robot IRB 2400 and an automated storage and retrieval system (AS/RS).

In the FMC-UnB the parts with non-concentrical features (C Axle) can be produced in the Galaxy 15M turning center. In the SOCIESC the movement of the part from the lathe to the machining center is necessary, because they are separated, and, consequently, setup changes are also necessary.

Figure 3 : FMS SOCIESC (http://www.grima.ufsc.br/sociesc/fms2/FMS2.htm).

The third system (Fig. 4), situated in UFSC (Florianópolis - SC), is composed only for a lathe CNC Romi Mach 6. This system only makes parts with concentrical features. In this case the presence of an operator to feed the lathe is necessary.

Figure 4: Lathe UFSC

3.2. ERP Manufacturing

The ERP Manufacturing is a web-based system, written in pure Java and Java for web development (JSP and Servlets), that makes the virtual company management. The management is composed by: the control of users' accesses via internet, the integration with the CAD/CAPP/CAM; the CAP, the integration with the management units of the distributed shop floor and the administrative activities of the company. All these modules are described as follow. The preliminary website of the WebMachining Company is shown in Fig. 5.

Figure 5: The preliminary website of the WebMachining Company

3.2.1. Institutional module

The institutional module is where the employees of the WebMachining Company perform the administrative and operational activities of the company.

The administrators are the responsible ones for registering new employees, excluding or modifying a register of an employee, modifying values for the production cost calculation of each shop floor, seeing monthly profits and expenses, and seeing the systems production by using Gantt graphs shown by the system.

Each shop floor has operators who have some functions as to register suppliers, to update supply of tools, to order buying materials, to register expenses of the month of the system, to get the master plain of production of the day for its system, etc.

3.2.2. Commercial module

After having access to the site of the WebMachining Company, the customers enter in the commercial module, make the login/registering in the system and finally the page with the customer menu is available. In this page the customer can make a new work order (WO), see the work order status, modify or cancel a work order and modify its registered data.

This is the first stage in the production process of the company and one of most important. It is in this stage that the customer registers information of the priority, the type of the part and the batch size.

The customer priority can be the production time (the batch must be manufactured in the lesser possible time, thus becoming the work order most expensive) or the production cost (most important it is not the time, but the final batch price).

When the costumer defines the type of part, it informs to the system if exists some prismatic part in the project or if it is purely rotational. This definition is the first decision making of the system. It happens because only the FMS - SOCIESC is capable to produce prismatic parts. With this first decision the others two possibilities of manufacturing are eliminated.

3.2.3. Integration with the Part Development Environment

The part development environment is composed by the WebMachining and CyberCut systems. In this work the WebMachining is used for the project of rotational parts and the CyberCut for prismatic parts.

Then the preliminary informations of the work order are registered, the ERP shows to the customer, via servlet, a CAD interface of one of the two tools, depending on the informed part type. In this interface the customer makes the part drawing. With this draw, the system does the process planning (CAPP), it include in data base informations of the machining operations, the time of each machining operation, the list of tools to be used in the manufacturing process, and NC program to be sent to one of the three management units. These informations are primordial in the decision making of where the part will be manufactured.

3.2.4. CAP – Computer Aided Production

The production planning in the PROMME is divided in two parts: the decision making, that defines in which shop floor the part will be produced, and the production programming composed by the master plain of production, by the formation of the part families and by the production scheduling.

Decision Making

The decision making is made considering basically the production capacity of the shop floor and the customers' priorities. The algorithm as follows brings the detailing of how the decision making is made:

Decision Making Algorithm

1. If (Part Type = prismatic)
    - 1.1. It initiates CyberCut
    - 1.2. If (Priority = cost)
        - 1.1.1. It calculates the production cost and the maximum production time
    - 1.3. Else, It calculates the production cost and the minimum production time
2. Else
    - 2.1. It initiates WebMachining
    - 2.2. It compares WO tools with systems tools
    - 2.3. If (Priority = cost)
        - 2.3.1. It verifies the sending type
        - 2.3.2. It calculates the sending cost + production cost for each system and gets the lower
        - 2.3.3. It calculates the maximum production time
    - 2.4. Else
        - 2.4.1. It verifies which system has the lesser number of WO to be produced
        - 2.4.2. It calculates the production cost and the minimum production time

The total time of production of the work orders is calculated based on times of machining operations, available in data base, and on setup time of tools. The shop floors work sixteen hours per day, seven days per week. According to the production times of the parts, a scheduling is made for each day of the week.

The calculation of the minimum time of production is made analyzing the work orders in the data base. All work orders have an end date, i.e., the foreseen date that the production will be concluded. Every time that the system has to preview when will be the conclusion of a work order, a search in the database is made to know the next date available to manufacturing the batch. The result of this search is shown to the customer to it decides if it confirms or not the batch production. The batch will just only be scheduled if the customer confirms the production of the work order.

The maximum time of manufacturing, that is the same for the all shop floor, is one month after the date that the work order entered in the system. As in the previous case, the batch will just only be scheduled if the customer confirms the production of the work order.

Production Programming

The production programming, as described previously, is composed by the master plain of production, by the formation of the parts families and by the production scheduling.

The master plain of production groups the work orders, created by the customers and included in the database by the system, to their respective shop floor. The master plain makes possible to know from which shop floor the WO is.

For the formation of the parts families was made an adaptation of the algorithm of rank order proposed by King (1980). In this case, the parts that have the same setting and tools characteristics are grouped in a same family. The parts are grouped using the list of tools included in data base by the part development environment. The suitable algorithm is shown as follow:

Part Family Algorithm

```
1. boolean flagColumn = false, flagRow = false
2. While (!flagColumn && !flagRow)
        2.1. For each tool-part matrix column
                2.1.1. It calculates the column binary total weight
        2.2. If  the column weights are orderly ascendant
                2.2.1. flagColumn = true
        2.3. Else, it sorts the column weights in ascendant order
        2.4. For each tool-part matrix row
                2.4.1. It calculates the row binary total weight
        2.5. If the row weights are orderly ascendant
                2.5.1. flagRow = true
        2.6. Else, it sorts the rows in ascendant order
```

This algorithm groups parts families to be produced with the same group of tools. This prevents that a new setup of tools has to be made every time that a new part is processed.

The production scheduling is made in the process of decision making because the foreseen date for the manufacturing must be shown to the customer when the WO is made and the customer must confirm if it accepted or not the foreseen date. The work order will only be included in the master plain of production if the customer accepts the foreseen date. The order that the parts families are produced in a day does not matter. The most important is that the work orders are made until the date that they had been shown to the customer.

3.2.5. Integration with the Management Units of the distributed shop floors

The integration with the management units (MGU's) is made remotely, via data base. All the WOs to be produced are into the master plain of production. The remote operators of each shop floor connect via internet with the web server and get the work orders to be done in the day. The MGUs are responsible for the success of the production. They have to make the control of the equipments and all the production programming in the shop floor.

4. SYSTEM MODELING

4.1. IDEF0

According to the IDEF0 standard (1993), IDEF0 may be used to model a wide variety of automated and non-automated systems. For new systems, IDEF0 may be used first to define the requirements and specify the functions, and then to design an implementation that meets the requirements and performs the functions. For existing systems, IDEF0 can be used to analyze the functions the system performs and to record the mechanisms (means) by which these are done. The IDEF0 methodology also prescribes procedures and techniques for developing and interpreting models, including ones for data gathering, diagram construction, review cycles and documentation.

Figure 6 shows the IDEF0 modeling of the PROMME:

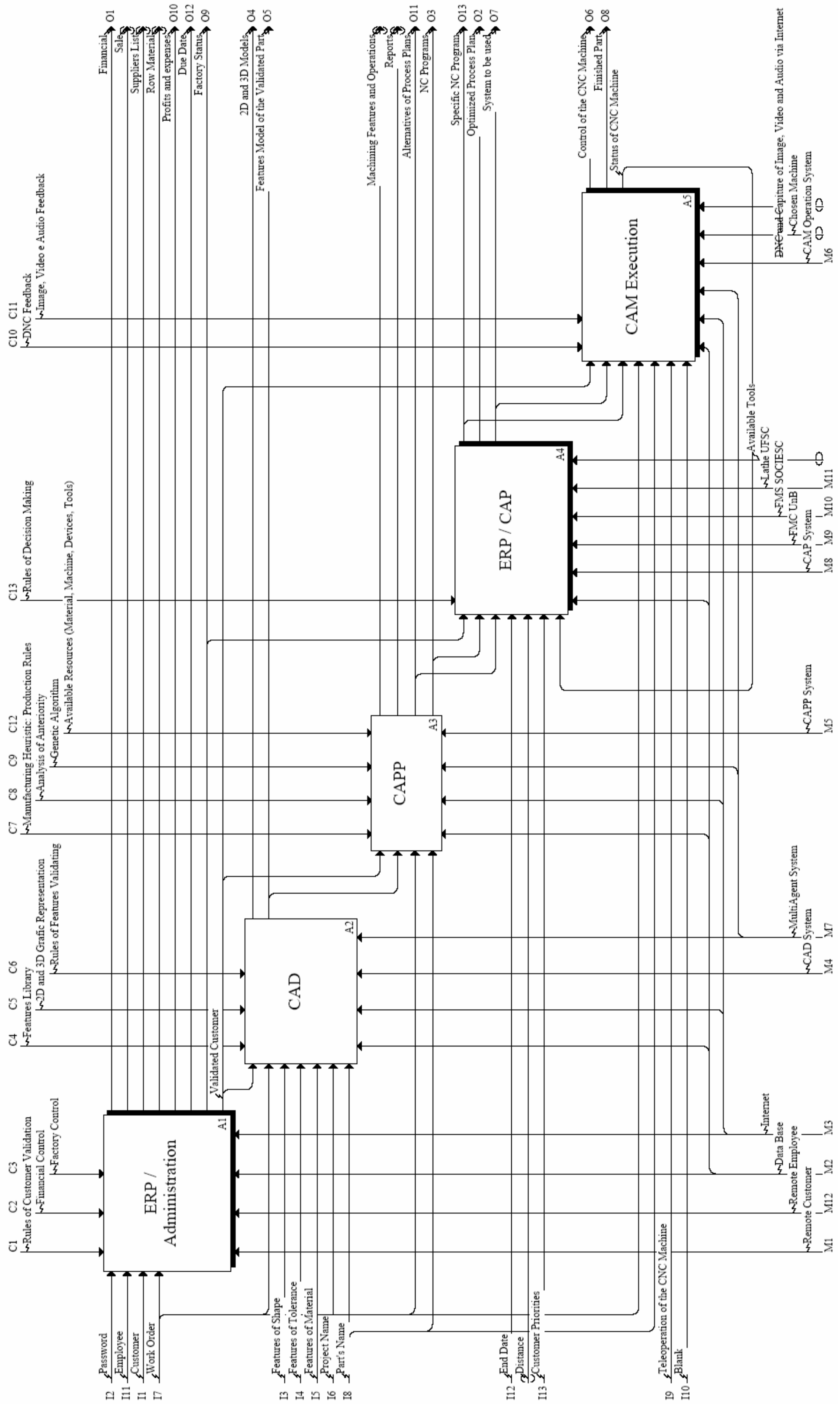

Figure 6: IDEF0 modeling of the PROMME.

4.2. UML

In the field of software engineering, the Unified Modeling Language (UML) is a standardized specification language for object modeling. UML is a general-purpose modeling language that includes a graphical notation used to create an abstract model of a system, referred to as a UML model. There are lots of diagrams to model a system.

In the Unified Modeling Language, a package diagram depicts how a system is split up into logical groupings by showing the dependencies among these groupings. As a package is typically thought of as a directory, package diagrams provide a logical hierarchical decomposition of a system. Figure 7 shows the package diagram of the PROMME.

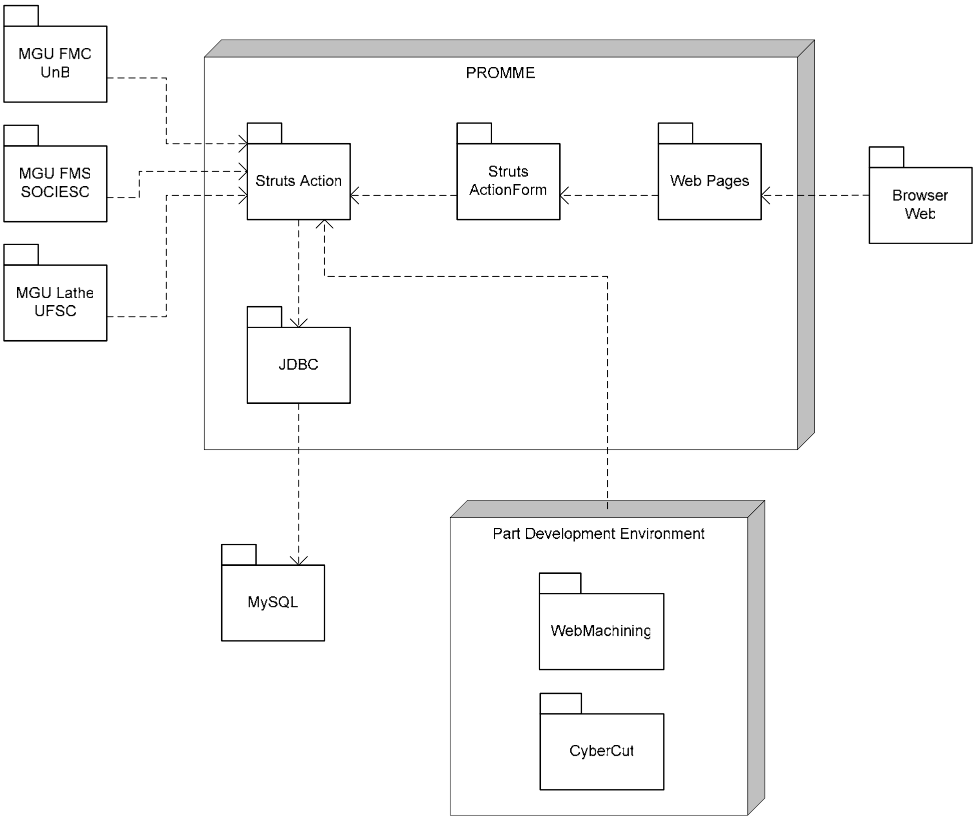

Figure 7: UML Package Diagram - PROMME Architecture

5. CONCLUSIONS

The PROMME methodology contains a new concept for production management. The PROMME has a web based system, an ERP written in Java language, that controls distributed systems no matter where they are located.

The control is made using e-manufacturing concept that integrates the remote accesses of users (customers and employees), the received customers orders, the engineering (CAD/CAPP/CAM), the distributed shop floor, sales, financials and supply control.

This integration allows the customer to execute operations and necessarily processes to design and produce the parts with a high amount of efficiency and flexibility, without have the necessary equipments. The integration also allows the employees to do the company activities remotely.

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