A Layered Software Architecture for the Management of a Manufacturing Company

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In this paper we describe a layered software architecture in the management of a manufacturing company that intensively uses computer technology. Application tools, new and legacy, after the updating, operate in a context of an open web oriented architecture. The software architecture enables the integration and interoperability among all tools that support business processes. Manufacturing Executive System and Text Mining tools are excellent interfaces, the former both for internal production and management processes and the latter for external processes coming from the market. In this way, it is possible to implement, a computer integrated factory, flexible and agile, that immediately responds to customer requirements.
Keywords: *ICT, Service Oriented Architecture, Web Services, Computer-Integrated Factory, Application Software*

1 Introduction

We define ICT-intensive enterprise a company that makes a heavy use of computer technologies in both management and production processes. In this type of company, internal and external processes are completely automated in a web-oriented and open infrastructure that provides an integrated and interoperable architecture. In a global market to be competitive, the enterprise must be agile and efficient in the management of the information flow. Agility [1] means high flexibility, thin structure, rapid response and high speed in the processing and transmission of information.

Actually, inside companies, there are a lot of software that are used stand-alone and it is necessary to create a cooperation environment where different tools can exchange useful data.

In this paper we describe an original layered software architecture, open and service-oriented, to integrate and make interoperable any business process.

The software that interfaces management and production tools is the Manufacturing Executive System (MES) [2] while a software of Text Mining [3] is a software that interfaces external textual information and Enterprise Resource Planning (ERP) or Enterprise Content Management (ECM). By these tools it is possible to implement a Computer Integrated Factory (CIF) that automates the management of internal and external business processes.

The paper is structured as follows: in the next section we show the literature and software evolution while in the third section a software infrastructure of an ICT-intensive enterprise is presented. In the next three sections respectively, Technology, Application and Network Layer are discussed. Then an application example of the model is shown. Finally some conclusion is drawn.

2 Literature review

Application software, used inside companies, can be classified in two classes: Management Software (MS) or Enterprise Content Management (ECM) to manage business information and Industrial Software (IS) to automate productive cycle.

Inside enterprises, there are different types of business contents, from a generic document to a complex report, that could reside in Internet, intranet or in stand-alone computers.

Over time, in the Office Automation, from simple spreadsheets as Visicalc we passed in advanced programs of Office Productivity Tools (OPT). The monomedia static document of the past were overcome from a dynamic multimedia and collaborative document where everyone can express own reviews and make a cooperative workgroup like to Computer Supported Cooperative Work (CSCW) [4]. Nowadays the world is interconnected, people work in teams, collaborate on projects distributed around the globe. Groupware is a flexible and customizable software that supports and encourages teamwork, exploits the network infrastructure and facilitates the automation of document flows.

The Workflow Management System (WFMS) [5] was born in 80s as trend of office systems and it is integrated into processes that manage, trace the revisions and the entire production cycle of business documents from the creation to the diffusion at different units. Software modules are wedged like to an ordered assembly line that distributes information [6].

The birth of Enterprise Resource Planning (ERP) [7], in 90s, allowed to companies to manage, synchronize and integrate business functions optimizing available resources. The ERP is primarily an organizational and managerial method to optimize operational activities of a manufacturing company. ERP manages customized orders and integrates business cycle and all aspects of the business: planning, manufacturing, sales, finance, procurement, logistics and marketing. ERP, working for processes, has led the enterprises to re-engineer deeply business processes by the Business Process Redesign (BPR) methodology [8]. The ERP allows the reduction of the delivery and cycle time and improves the response to customer needs [9]. The evolution of ERP in ERP II or Extended ERP (EERP) includes the Customer Relationship Management (CRM) and Supply Chain Management (SCM).

Regarding the Industrial Software, the Material Requirement Planning (MRP) that planned material requirements, is evolved in the Manufacturing Resource Planning (MRPII), that added to materials' supply the planning of resources involved in the production scheduling.

The diffusion of microprocessors (mid-70s) has facilitated the development of digital Computer Numerical Control (CNC) machines, Programmable Logic Controller (PLC) and Robot Control. All this has encouraged the development of Computer Aided Technology (CaT): Computer Aided Design (CAD), Computer Aided Manufacturing (CAM) and Computer Aided Engineering (CAE). The CAE software supports the engineering aspect like design calculations, definition of methods, timing, cycles and business tools.

Nowadays all CaTs can be integrated in the Product Lifecycle Management (PLM) [10] useful in the product collaborative development that involves many company's partners.

In recent years, to fully automate the production chain, many tools, hardware and software, are using: Robots, Flexible Manufacturing System (FMS), Computer Integrated Manufacturing and Engineering (CIM/CIME), Modular Integrated Robotized System (MIRS). The flexible manufacturing system FMS has the ability to automatically produce different products changing only the executive program of machines. With the Computer Integrated Manufacturing (CIM) [11] the automation of the company, that combines all the business activities of planning, design, production, warehousing and sales, is realized. The information flow is automated from the arrival of an order to the delivery of the finished product.

Regarding the tools for the management of logistic processes we can consider the Intelligent Transportation System (ITS), Radio Frequency IDentification (RFID), Geographic Information System (GIS) and Positioning System (GPS) based on mobile and wireless technologies for tracking the location of products and carriers.

In an automated context it is important the Intelligence in Manufacturing Systems (IMS) (www.ims.org) program. This is a promising systemic paradigm for organizing humans and machines into a networked system evolving into an extended/virtual enterprise for world-wide manufacturing goals.

3 The software infrastructure of an ICT-intensive enterprise

In modeling an ICT-intensive company, we take in consideration the following Software Infrastructure (Figure 1):

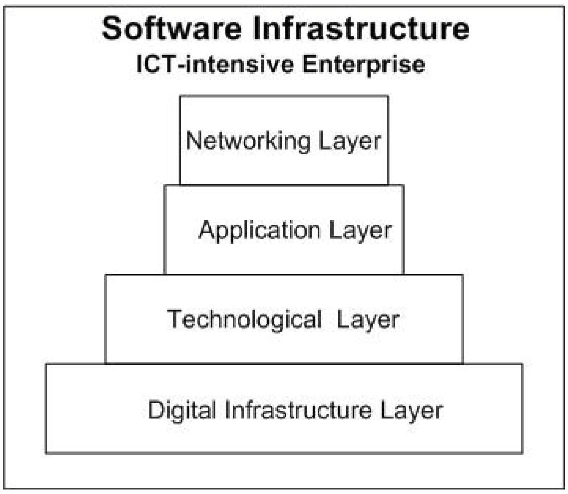

Fig. 1. Software Infrastructure in an ICT-intensive Enterprise

The digital infrastructure is the basic digital platform with PCs, standalone or linked in networking and operating systems.
Technological layer is an architecture, open, flexible and service-oriented. All software tools have a modular structure that recalls useful services for a particular business goal.
The application layer is a set of software applications that supports different functions and business processes.
The networking layer includes the software that interacts with external environment: customers, suppliers, partners and all market players.
The ICT-intensive company must have a robust, integrated, interoperable and intelligent infrastructure where software modules can exchange data to automate, in an efficient and effective manner, business processes.

4 Technological layer of an ICT-intensive enterprise

The layer of an ICT-intensive manufacturing company uses an integrated, interoperable and intelligent service-oriented architecture (SOA) [12].
The SOA, platform in-depended, facilitates the interaction between different software, processes and business units. SOA increases flexibility and adaptability of different services that can be combined to satisfy business requirements. The software is organized as a collection of services published on a web infrastructure and can be used by multiple applications.
Every process' application, inside the enterprise, is seen and considered as an internal service. For example a service could be the processing of an online order or the monitoring/ traceability of a product from the magazine to the final customer. In a context of Service Oriented Architecture (SOA) and Software as a Service (SaaS) or Cloud Computing, different services can be reused, modified or combined (mash-up) to create new services for satisfying workload changes and the evolution of applications.
SOA exploit the web service technology [13] that allows the dynamic composition of business application using the web as a medium.
The Service Open Architecture presents the following main components:

- *Web Services (WS):* collection of services by a web technology. The services interact with the calling program through input and output parameters
- *Universal Description Discovery and Integration (UDDI):* directory of available services (recorded and indexed)
- *Web Services Description Language (WSDL):* for describing services and access modality

- *Simple Object Access Protocol (SOAP)*: protocol for the service request. It is a protocol independent from the platform and programming languages.

Web Services describe a collection of accessible operations by an eXtended Markup Language (XML). The service provided by web services is described with a WSDL document and published into an UDDI repository that offers possibilities for dynamic collaboration. The framework SOAP transports the information contained in request messages and the processing method.

SOA supports also other processes:

- *Discovery*: finding suitable services for some goal
- *Selection*: finding the best available service
- *Compensation*: finding a service for mitigating undesidered effects
- *Replacement*: replacing a service with another one
- *Design*: invoking services from program
- *Monitoring*: controlling the execution of services
- *Auditing*: verifying that the execution of a service has followed a predetermined process

The web services framework also offers possibilities for a flexible process integration. The Business Process Execution Language (BPEL), process' orchestration language, provides possibilities for the integration of processes.

In the SOA context it is important the Enterprise Service Bus (ESB). This bus has the goal to decouple the processes from the services and executes, in particular, the following functions:

- *Routing*: to direct the request of the service where it is actually available
- *Protocol conversion*: to transform, syntactically and/or semantically the protocol; for example a service request via SOAP in an invocation of the service via Java RMI
- *Data enrichment*: to add some parameters required by the service that are not included in the request

The technological layer, that uses a web services architecture, is represented in Figure 2. The specific process (enterprise application) requires a service (Service Request) to SOA platform. The web service responds and activates a Service Delivery. The system can monitor and track the service to prevent malfunctions.

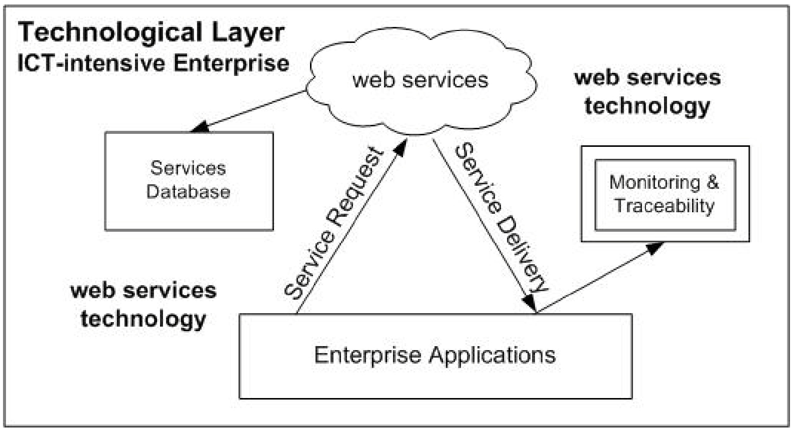

Fig. 2. Delivery implementation by web services technology

Currently, inside the enterprise, it is necessary to consider new business requirements as a set of functions and services and publishing them as web services.

Companies that decide to transfer on the web (part of) their applications and transactions must do so understanding that this operation involves a complete revision of the existing infrastructure. Actually, many companies convert their legacy systems and develop applications that allow to share part of important processes with customers, partners and suppliers. The idea is to facilitate the full development of standardized and reusable

software components that can interact among themselves.
We must think to services as routines, which are available in the web, published in a directory. Different users can use these services that can be variously combined. The integration of services can be executed at interactive (controlled by users) or batch (controlled by process) levels.
The most common techniques of services processing are the filtering, which allows to use the output of a service as input to another one or the orchestration which uses the script language to control the sequence of an information flow during the execution of a service.
To transform a legacy application in a web service, we can use appropriate wrappers which add useful information to the old code in order to expose it as a service.
In the future, in a context of the semantic web or web 3.0, the SOA will evolve in a Semantically-Enabled Service-oriented Architecture (SESA) [14]. With this advanced semantic-oriented architecture, we can use semantic web services as infrastructure and directly express problems as goal without requiring services for the solution of the specific problem. Moreover we can model business processes as goals and support them by applications dynamically assembled using the goal-based discovery.

5 Application Layer of an ICT-intensive enterprise

In this section, we analyze the application software that operates, as a service, in a SOA context. The legacy software is transformed in web services easily accessible via browser. Application software, as a set of services, used inside enterprise, can be classified in two classes: Management Software as Service (MSaS) to manage business information and Industrial Software as Service (ISaS) to automate the productive cycle. In Figure 3, that represents the Application Layer, we have classified the MSaS in main tools like to ERP, CRM, SCM and ISaS in CAD-CAM-CAE-PLM-FMS-SCADA-MEMSS.

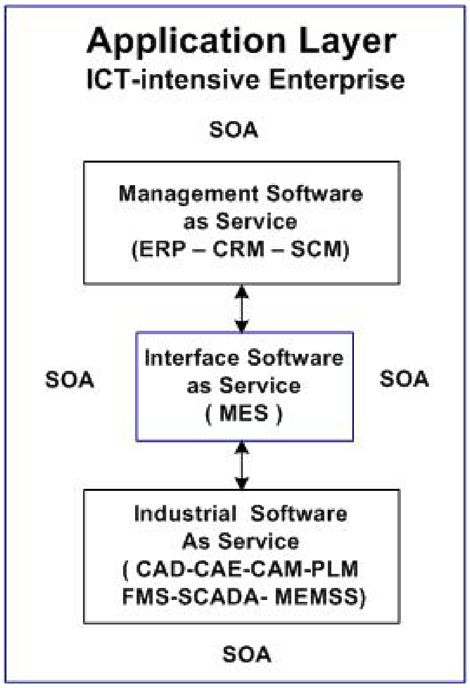

Fig. 3. Application Layer

The module of Manufacturing Execution System (MES) allows to describe operational procedures for the manufacturing. MES is the digital “nervous system” capable to coordinate and synchronize production processes, the flow from ERP/PLM to production plant (FMS, PLC, Robots,...) and to distribute tasks to other sub-level systems.
MES receives information from ERP/PLM on working cycle and converts it in machine commands for production sequences.
This production system aligns more effectively areas of maintenance and production with business goals in order to optimize the asset performance management. MES integrates the production in the supply-chain and gives the visibility on what happens in the factory.
Thanks to this module it is possible to automate the productive cycle inside a Computer-Integrated Factory (CIF) [15].
In Figure 4 we show an original detailed schema of an Application Layer in a fully automated factory.

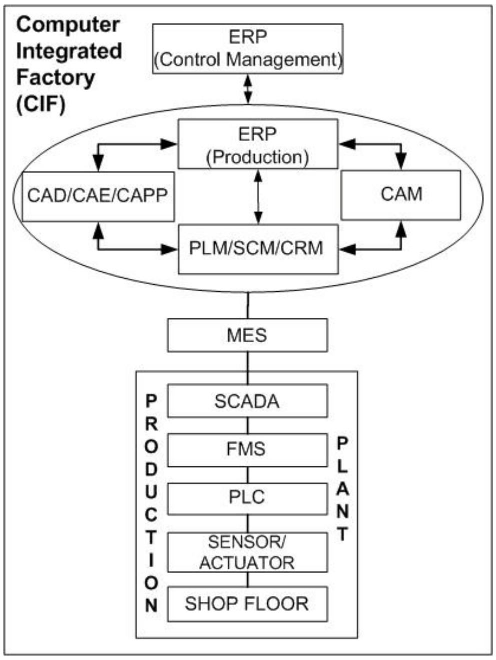

Fig. 4. Example of an application layer: a full automated factory

ERP, software application, manages and controls the entire enterprise. An ERP includes different modules supporting a variety of business functions such as finance, administration, logistics, manufacturing, marketing and so on. In a Computer-Integrated Factory (CFI) it is important the production ERP module that manages information on materials (bill of material, suppliers and customers order), production (scheduling and working orders) and distribution (product delivery, transportation and shipping). This module exchange data with other software of Computer Aided technology (CAD, CAM, CAE) and Supply Chain Management (SCM) like to Customer Relationship Management (CRM) and Product Lifecycle Management (PLM).

PLM is an important corporate application. Generally the term "lifecycle" represents a set of steps for the product development: conception, design, planning, realization, distribution and delivery. PLM manages all contributions and information exchange of global participants, like to business partners, suppliers and customers. PLM increases communication, coordination and collaboration with partners of an extended enterprise and provides a collaborative space interconnected where stakeholders can access and collaborate, in real time, in products development.

Integrating these software modules of Management Software we can obtain useful information to control production plant: Flexible Manufacturing System (FMS) and Shop Floor (SF) that represent the industrial software. The production plant includes FMS, PLC, Sensor/Actuator, shop floor (mechanical devices).

As shown in the Figures 3 and 4, the MES performs an essential task. It is a “bridge” between management and industrial software allowing the transformation of business data in information useful to automate the manufacturing.

In a Computer-Integrated Factory it is important the control and monitoring of electronic and mechanical devices at different levels (area, cell, machine,…) of the plant production by specific control software (Table 1):

Table 1. Software Control for plant elements

Manufacturing Plant Elements	**Software Control**
Area	Supervisor Control and Data Acquisition (SCADA)
Cell	Flexible Manufacturing System (FMS)
Machine	Programmable Logic Control (PLC/CNC)
Sensor/Actuator	Sensor/Actuator Control (S/AC)
Mechanical Devices	Shop Floor Control (SFC)

	Micro Electro-Mechanical System Software (MEMSS)

The first level of monitoring system is the Supervisor Control and Data Acquisition (SCADA) [16] that supervises the working productive area. The system SCADA manages and controls operating processes in the following stages: data processing, production and processes setting, alert management, results analysis and screen visualization.
The supervision is supported by web technologies, accessible from user by web browser or mobile phone. In the SCADA level, real time requirements are reduced. These requirements are higher at lower level (mechanical devices).
Each device of production plant (FMS, PLC/CNC, sensor/actuator, mechanical devices and Micro Electro-Mechanical Systems (MEMS)) is equipped with an Ethernet card and presents an integrated web server as single point of access for the diagnostic, check and testing. The use of intelligent devices involves a closer interaction among processes and automation.
MEMS are miniaturized electromechanical systems of various kinds (mechanical, electrical and electronic) that are integrated on a single silicon substrate having the function of sensor and actuator. By MEMS it is possible to start automatic assembly lines and production processes. In Table 1 we have named the software that manages MEMS as MEMS Software or MEMSS.

6 Networking Layer ICT-intensive Enterprise

The networking layer is represented in Figure 5.
The ICT-intensive enterprise communicates with the external environment by a collaborative software that exploits web technologies and in particular web 2.0 (chat, forums, blogs,...) tools.
In the value chain, the collaborative software that manages the information exchange among all enterprise stakeholders, such as customers, suppliers, commercial partners and other companies, has become a key factor and an important tool for acquiring competitive advantages, in an increasingly turbulent business environment.
Since the exchanged content, by different web 2.0 tools, has a textual format, it is important to use a Text Mining software [17] to process this information and integrate it with the ERP software.

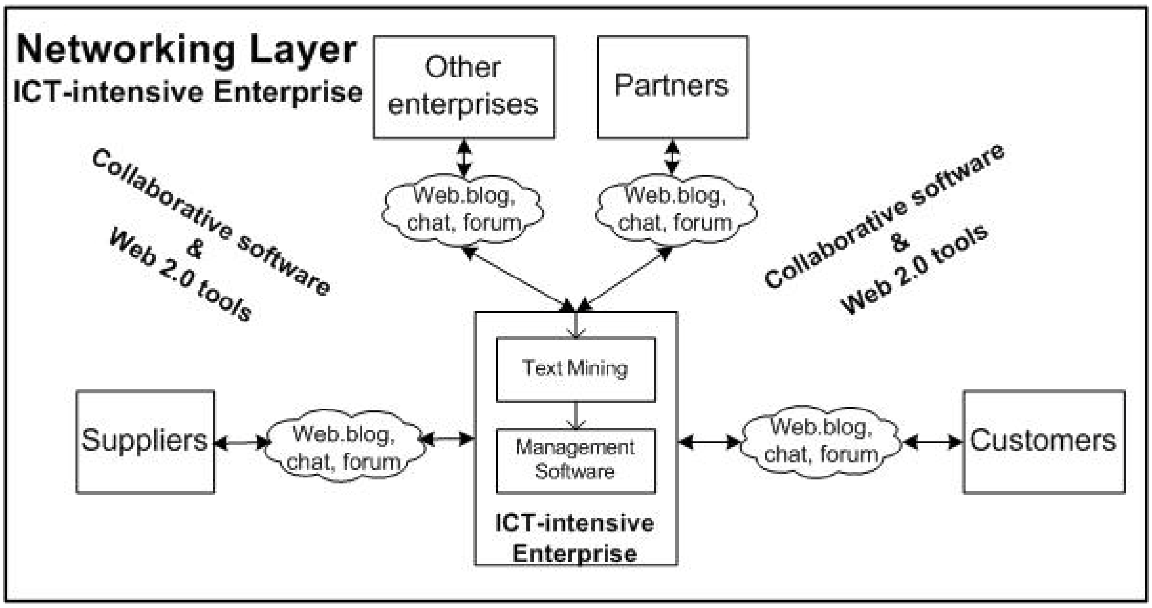

Fig. 5. Network Layer in an ICT-intensive Enterprise

Text Mining (TM) (Figure 6) is a set of techniques obtained as a generalization and contextualization of those used in Knowledge Discovery in Databases (KDD) but with information sources in textual format.
If textual data is transformed in structured data, Data Mining (DM) techniques can be applied.

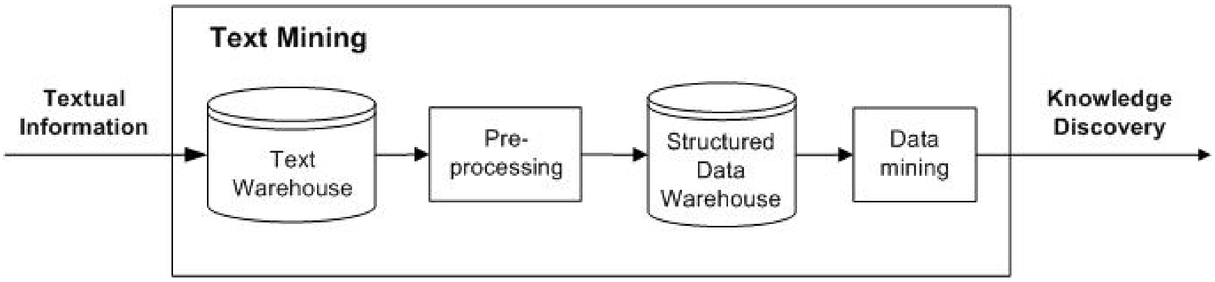

Fig. 6. Text Mining

By algorithms of Data Mining (DM) [18] hidden relationship and useful knowledge are extracted from data contained in a data warehouse.
Since texts are written in natural language, to process and transform them in structured data, it is very important to apply a specific preprocessing module.
The goal of this module is to obtain significant sentences and words for each text expressed in a web post.
The preprocessing consists of the following main steps:

- *Sentence extraction*
- *Tokenization*
- *Stemming*
- *Lemmatization*
- *Part of speech*
- *Index terms selection*

In the *sentence extraction* we extract the phrases that finish with a point, exclamation point or a question mark. Inside each sentence we eliminate all stop words such as comma, articles, prepositions and conjunctions.
In the *tokenization* stage, a sentence is divided into units called tokens [19] where each token is a word or something as a number, a date, etc... The token boundary is represented by a white space (space, tab or the beginning of line).
The *stemming* extracts the root of single words, removing affixes and endings. For example inhibits, inhibition, inhibited have as common root the term inhibit.
Lemmatization aims to search single terms from the word ending. Respect to stemming phase the lemmatization must disambiguate different forms in a specific context. For example does the term songs derive from the verb sing or from the word song?
In the *Part of Speech* (PoS) every word of a sentence is labeled by a tag with the correct part of speech: article, noun, verb, adjective, etc. The tagging is a case of limited syntactic disambiguation. In the case of words that belong to several syntactic categories, it determines which of these categories is the most plausible in a given context.
In the *index terms selection* all those words as verbs, adverbs, pronouns, nouns, adjectives and nouns are taken in consideration and transformed in numbers and in particular in a (n x m) sentences-words matrix where the generic element w_{ij} represents the number of occurrence of a word j in a sentence i, with i = 1 .. n and j = 1.. m.
Therefore the output of the pre-processing phase is the representation of the document by a numeric array where will be possible to apply techniques of Data Mining.
Text Mining could use also modern semantic technology [20] to understand the significance of the text. In this case, to resolve the ambiguities of the text we can define rules of grammar and semantics to understand the meaning of the words in individual sentences. In a semantic context it is important to use specific ontologies.
Data obtained from Text Mining module could be interfaced with Management Soft-

ware (MS). This knowledge is useful for Business Intelligence and Enterprise Applications.

7 Application example of Layered Software Architecture

As a practical application of our layered framework we can consider the following example: the delivery of products from a manufacturing company to the final customer. A specific request (SERVICE REQUEST) for the product delivery (Technological Layer) is sent to the SOA-oriented model. For the answer, the system must monitor all internal and external available carriers that are available to execute the PRODUCT DELIVERY. In this case, the software interface (Application Layer) starts a scanning of all carriers working with the company (Networking Layer). After the scanning it is possible to find the available carrier. The delivery path is monitored by RFID/GIS /GPS technology. Even in this case we use a software that interacts with external environment (Networking Layer).

Relationships among all subjects involved in the delivery task (supply chain management), in a web-services context, is represented in Figure 7 [21]. In this figure, the central subject is the final customer. The customer may be served directly by manufacturer or indirectly by other players of the supply chain: supplier, distributor, wholesaler, retailer.

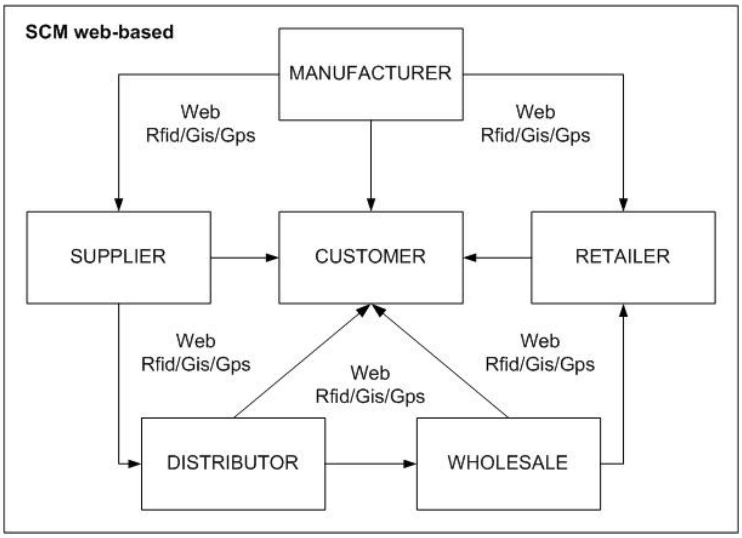

Fig. 7. A model of SCM supported by web technologies

It is important to annotate the direction of the arrows linking various actors. The customer can obtain products/services directly from the manufacturer or from subjects of next stages. All products and carriers are provided with RFID/GIS/GPS tags. Requests of service and delivery execution are implemented via web services.

By this model, we can obtain several advantages in terms of efficiency in the supply chain like to the optimization of the processes' automation, reduction of delivery times and the monitoring of products and carriers.

The sensor network, that monitors the operations in real time, plays a crucial role to improve the global system and in particular the information flows and performances.

8 Conclusions

In this paper, a model of a software infrastructure is proposed for the management of an ICT-intensive manufacturing. Legacy software, management and industrial tools, can be redesigned in a form of web-oriented services and can be integrated with an interactive and collaborative software that exchange data with the external environment. In this way it is possible to implement a full computer-integrated factory to automate all management and manufacturing processes. For the integration and the interoperability, dynamic interfaces like Manufacturing Executive Systems and Text Mining represent important solutions. This software infrastructure supports the agility of enterprises. In a global and competitive context it is important that companies respond quickly to the fast changing of the business environment. It is also important to process, in real time, useful information for problem solving and decision making operations. The company must know how to react quickly to unexpected situations. The framework described in this paper is useful to implement a full automation inside the company, where all internal assets and global participants of the supply chain (business partners, suppliers, customers) can collaborate in the product development.

In the future we think to develop some experimental interface for the best implementation of the model.

References

[1] D. C. Plummer and D.W. McCoy "Achieving agility: The view through a conceptual framework", *Garter Research*, 28 April 2006, pp. 1-5.

[2] J. Kletti "Manufacturing Execution Systems". In *Springer-Verlag*, NewYork, Inc., 2007, pp. 272.

[3] J. Gelernter and M. Lesk "Text mining for indexing", In *Proceedings of the 9th ACM/IEEE-CS Joint Conference on Digital Libraries* (Austin, TX, USA, June 15 - 19, 2009). JCDL '09. ACM, New York, NY, 2009, pp. 467-468.

[4] P. Liu, J.M. Laffey and K.R. Cox "Operationalization of technology use and cooperation in CSCW". In *Proceedings of the 2008 ACM Conference on Computer Supported Cooperative Work* (San Diego, CA, USA, 2008). CSCW '08. ACM, New York, NY, 2008, pp. 505-514.

[5] C. Combi and G. Pozzi "Architectures for a temporal workflow management system," In *Proceedings of the 2004 ACM Symposium on Applied Computing* (Nicosia, Cyprus, March 14 - 17, 2004). SAC '04. ACM, New York, NY, 2004, pp. 659-666.

[6] M. D. R-Moreno, D. Borrajo, A. Cesta and A. Oddi "Integrating planning and scheduling in workflow domains", *Expert Systems With Applications* Volume: 33, Issue: 2, August 2007, pp. 389-406.

[7] J. Yongjean and Y. Ki-Heung "A study on an environment of ERP introduction", *Info-tech and Info-net, Proceedings ICII*, vol. 6, 2001, pp. 84- 89.

[8] M.-Y. Cheng, M.-H. Tsai and Z.-W. Xiao, "Construction management process reengineering: Organizational human resource planning for multiple projects", *Automation in Construction* Vol. 15, Issue: 6, November, 2006, pp. 785-799.

[9] S. P. N. Celeste, G.G. Gable and T. Chan "An ERP-client benefit-oriented maintenance taxonomy", *J. Syst. Software*. 64, 2 November, 2002, pp. 87-109.

[10] D. Consoli "The Product Lifecycle Management in the Enterprise 2.0". *In Proceedings of the International Conference on ICMMS 2008*, Imperial College Press, 2010, pp. 27-32.

[11] S. V. Nagalingam and G. C. Lin, "CIM-still the solution for manufacturing industry", *Robot. Comput.-Integr. Manuf.* Vol. 24, No. 3, June 2008, pp. 332-344.

[12] A. Dan, R.D. Johnson and T. Carrato "SOA service reuse by design". In *Proceedings of the 2nd international Workshop on Systems Development in SOA Environments*, Leipzig, May 11 - 11, 2008, *SDSOA '08. ACM*, New York, NY, 2008, pp. 25-28.

[13] Q. Yu, X. Liu, A. Bouguettaya and B. Medjahed "Deploying and managing Web services: issues, solutions, and directions". *VLDB Journal* 17, 3 (May. 2008), pp. 537-572.

[14] D. Fensel, M. Kerrigan and M. Zaremba, *Implementing Semantic Web Services: The SESA Framework (1 ed.)*, Springer Publishing Company, Incorporated, 2008.

[15] D. Consoli, "The Product Lifecycle Management in the Enterprise 2.0". In 1th International Conference on Management and Marketing Sciences, Athens, Greece, May 23-25 2008, Marketing and Management Sciences: *Proceedings of the International Conference on ICMMS 2008* edited by Theodore E Simos, Damianos P Sakas & Nikolaos Konstantopoulos, Imperial College Press, 2010, pp. 27-32.

[16] T. Kilpatrick, J. Gonzalez, R. Chandia, M. Papa and S. Shenoi "Forensic analysis of SCADA systems and networks". *Int. J. Secur. Netw. 3*, Inderscience Publishers, 2 (Feb. 2008), pp. 95-102.

[17] M. W. Berry and M. Castellanos editors, *Survey of Text Mining II: Clustering, Classification*, and Retrieval, Springer, 2007, pp. 254.

[18] L.A. Kurgan and P. Musilek "A survey of Knowledge Discovery and Data Mining process models". *Knowl. Eng. Rev.* Vol. 21, No. 1, Mar. 2006, pp. 1-24.

[19] J. J. Webster and C. Kit "Tokenization as the initial phase in nlp" in *Proceedings of the 14th conference on Computational linguistics*, Morristown, NJ, USA: Association for Computational Linguistics, 1992, pp. 1106-1110.

[20] L. Obrst, W. Ceusters and T. Janssen "Ontologies, Semantic Technologies, and Intelligence: Looking Toward the Future", *In Proceeding of the 2010 conference on Ontologies and Semantic Technologies for Intelligence*, IOS Press, Amsterdam, The Netherlands, The Netherlands, 2010, pp. 213-224.

[21] D. Consoli and F. Musso, "A new model of supply chain management in a web service oriented architecture". In *Proc. 5th International Conference "Business Excellence*, Brasov, October 15-16 2010, Vol. 1, 2010, pp. 117 - 120.

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