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Enterprise integration and interoperability in manufacturing systems: Trends and issues

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ABSTRACT

Recent advances in information and communication technologies have allowed manufacturing enterprise to move from highly data-driven environments to a more cooperative information/knowledge-driven environment. Enterprise knowledge sharing (know-how), common best practices use, and open source/web based applications are enabling to achieve the concept of integrated enterprise and hence the implementation and interoperability of networked enterprises. Enterprise integration and interoperability in manufacturing systems is a key concept to face the challenges of these new environments. This paper describes challenges, trends and issues that must be addressed in order to support the generation of new technological solutions.

1. Introduction

Integration in Manufacturing (IiM) is the first systemic paradigm to organize humans and machines as a whole system, not only at the field level, but also, at the management and corporate levels, to produce an integrated and interoperable enterprise system. Business process software and manufacturing execution systems (MES) are now available to meet the requirements of this fully computerised and automated integration. Major problems remain with respect to the interface between the enterprise corporate level and the manufacturing shop floor level, so that management and operation decisions within a closed loop are facilitated to pace the production according to the life cycle dynamics of the products, processes and humans inside and outside the enterprise. Today, networked business encounters recurrent difficulties due to the lack of interoperability between enterprise systems. The role of research in the field is to create upstream conditions of technological breakthrough to avoid that enterprise investment be simply pulled by the incremental evolution of Information Technology (IT) offer. However, the future relies on collaboration networks that can be created among companies, people and societies in order to generate shared knowledge and wealth. A number of important enablers are needed to support the creation of successful collaborative networks (CNs), e.g. common reference models, effective interoperability mechanisms and approaches, supporting infrastructures based on open architectures, design and engineering methodologies to instantiate/duplicate already successful cases, and standardized market technologies and tools.

Enterprise engineering models and tools are needed for a seamless integration of business and manufacturing models, in order to completely describe the information aspects of an integrated manufacturing system. However, up to date, although some high level standards in the area of enterprise modelling and integration are available; they are not yet widely recognized as such and not used in industry.

Future scenarios place information and communication technologies (ICTs) to be core in new developments. Digital mega trends such as: e-Tailing, e-Government, entertainment on demand, virtual education and a wide set of online services (finance, publishing, marketing) will be part of everyone life's. However all these applications and systems will require satisfying the following fundamental requirements [1]:

- enterprise integration and interoperability,
- distributed organization,
- model-based monitor and control,
- heterogeneous environments,
- open and dynamic structure,
- cooperation,
- integration of humans with software and hardware,
- agility, scalability and fault tolerance.

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The following technological areas have been defined to be core for the success of next generation manufacturing related to information and communication technologies [2]:

- adaptable, integrated equipment, processes, and systems that can be readily reconfigured,
- system synthesis, modelling, and simulation for all manufacturing operations,
- Technologies that can convert information into knowledge for effective decision making,
- enhanced human–machine interfaces,
- educational and training methods that would enable the rapid assimilation of knowledge,
- software for intelligent systems for collaboration,
- product and process design methods that address a broad range of product requirements,
- innovative processes to design and manufacture new materials and components,
- manufacturing processes that minimize waste production and energy consumption.

All of these areas are strongly related to the concepts of enterprise integration and interoperability, and therefore it is important to foster the application these concepts to support the generation of new technological solutions.

This paper summarizes the need for enterprise integration and interoperability in manufacturing systems and puts forward trends and issues important and relevant for future research work. The grand challenges may be classified according to the following areas in [1] (Table 1):

- collaborative networked organizations,
- enterprise modelling and reference models,
- enterprise and processes models interoperability,
- validation, verification, qualification and accreditation of enterprise models,
- model reuse and repositories.

2. The need for enterprise integration and interoperability solutions

2.1. Key concepts of enterprise integration and interoperability

Enterprise integration is a domain of research developed since 1990s as the extension of Computer Integrated Manufacturing (CIM). Enterprise integration research is mainly carried out within two distinct research communities: enterprise modelling and Information Technology. The notion of enterprise integration as it is understood in the frame of enterprise modelling refers to a set of concepts and approaches such as for example the definition

Table 1
Research challenges for enterprise integration and interoperability [1]

Challenges	Business	Knowledge	Applications	Communications (ICT)
Grand challenge 1. Collaborative networked organizations (CNOs)[27]	Business and strategy models	Knowledge about business processes and operations in CNOs	Collaborative software solutions	Reliable communication networks
	Reference models of CNOs	Knowledge about core competencies (resources based view)	Software to simulate operation to see parallelism and concurrency	Broadband
	Formalisms for modelling collaboration networks	Sharing principles and operation rules	Tools for monitoring and control of parallelism and concurrency	Wireless applications
Grand challenge 2. Enterprise modelling and reference models [11] [26]	Enterprise measurement systems (e.g. Balanced Score Card)	Description of skills, core competencies, organization roles and knowledge assets	Integration of enterprise applications (ERP, MES, SCADA, factory automation systems)	Open platforms and architectures
	Compensation systems based on enterprise performance measures	On line resources availability and capacity	Workflow management systems (WfMS)	Human computer interaction applications
	Model driven architectures	Balanced automatic vs. manual tasks	Computer supported cooperative work (CSCM)	Friendly user interfaces
Grand challenge 3. Enterprise and processes models interoperability [4] [12]	Integration of business information	Interoperability of models	Standards and interfaces	Standards
	Networked enterprises Ontology mapping and matching Consistent enterprise-wide decision-making structure	Standards (KIF, KQML) Shared Ontology Explicit knowledge models Knowledge management system	Interoperable databases Modular and reconfigurable systems Components based software solutions (plug in/plug out) Simulation software	Interfaces and mediators Interoperability
Grand challenge 4. Validation, verification, qualification and accreditation of enterprise models [22]	Reference models for validation, verification and qualification and accreditation	Ontology and formal modelling	Standards	Interpretability
	New business models evaluation for CNOs	Model-based manufacturing and control	Models formalization Safe systems	Standards
Grand challenge 5. Model reuse and repositories [19] [20]	Distributed business information systems	Ontology and formal modelling	Data mining	Standards
	Unified database enterprise models	Life cycle management information models	Databases and data warehousing Knowledge based Systems	Interfaces Interoperability