A business repository enrichment process: A case study for manufacturing execution systems

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ABSTRACT

A key characteristic of the software applications supporting manufacturing business processes is their heterogeneity. This is due not only to differences in their development and deployment, but also to the variety of processes and actors in complex organizations. Heterogeneity at the semantic level is one of the major problems in any process of interoperability and/or integration. There is therefore a need for developing new approaches and methods to ensure interoperability between different software solutions. In the context of a case study with a consortium of MES (Manufacturing Execution Systems) publishers, we propose a semantic alignment process of repositories used in the construction of a MES solution called "MES On Demand", using multiple applications and driven by business processes. Through the study of semantic heterogeneities, we use an enrichment-based alignment for business repositories applied to ISO/IEC 62264. Finally, we evaluate the contribution of this approach to enterprise maturity in the application of standards and reference models, using Nascio's Enterprise Architecture Maturity Model. This proposal, which is useful for practitioners and experts, is a contribution to academic study on semantic alignment for master interoperability.

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1. Introduction

Market requirements are constantly evolving and are demanding that companies seek new solutions and techniques to build information systems (IS) in line with their needs and strategies. Enterprise IS are often composed of several business applications such as Enterprise Resource Planning (ERP) systems, Manufacturing Execution Systems (MES), and Product Lifecycle Management (PLM) systems. A result of this trend is the need for companies' "integration". Integration can be seen as a process consisting in high levels of interaction between people, machines and applications, which enhances the synergy within a company [1]. Regarding IS, integration essentially involves the application's components. In some cases, components are loosely coupled to preserve their heterogeneity and autonomy. This is called the "interoperability" of applications, which is one way to facilitate integration.

Many projects and studies have been carried out to develop and design new approaches and corporate architectures in order to ensure the interoperability of systems at the technical and semantic levels. The service-oriented approach provide sound answers to the problems of technical interoperability. Indeed, it is essential that business applications remain capable of consistent interpretation of the data exchanged and the functions used. Semantic conflicts may arise during the exchange between applications. These conflicts may involve not only data [2] but also the business logic of applications [3]. It becomes vital to identify resulting conflicts and proceed to their resolution as soon as possible, preferably in the early stages of an integration project. The resolution of these semantic heterogeneities requires mechanisms to determine the correspondence areas and/or semantic conflict between applications.

Current research on semantic alignment uses mainly ontologies. Most of these ongoing development initiatives affirm that automation of alignment is difficult to achieve, and highlight the role of users in the validation of semantic alignment [4]. The semantic alignment between applications therefore remains an unresolved issue in the context of integration and systems interoperability, which requires an alignment process. Consequently, the role of experts in integration projects is critical. As business applications are based on either proprietary or

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standard business repositories, a way to tackle this research issue is to provide semantic alignment solutions for business repositories. In this paper we present a case study where a new alignment methodology enriches a given business repository by other business repositories. It provides experts with an assisted process of unidirectional semantic alignment of business repositories, using semantic check rules to help them solve any semantic heterogeneity problems that may exist between several business sources.

This case study is the result of an industrial initiative conducted by a consortium of manufacturing software publishers. They launched a "MES on demand" platform, using services from various packages, including Manufacturing Execution Systems (MES) and Supply Chain Execution (SCE). To allow such an "on-demand" MES to manage heterogeneity between the trades, software packages, and business reference models involved in the project, we formalize the knowledge of business processes and business objects that will be supported by applications and their interactions. Of course, this knowledge is implemented in different ways and often partially in each software package.

The capacity to build an "on demand" multi-publisher MES solution depends on the capacity to align business repositories, companies' needs, and functional layer components, which contains heterogeneous knowledge for the following reasons:

a Several software packages are more often involved and are heterogeneous;
b Industrial companies' requirements are expressed in their own business language and have to be mapped onto the repository language;
c Finally, the capacity to link a standard business repository and a standard web service of applications is a condition for mastering the implementation of the industrial company's business model in an orchestration of existing web services.

More often, aligning two structures (models, standards, etc.) means that for each entity (e.g. concepts and relationships) in the first structure, we try to find a corresponding entity that has the same meaning in the second structure [5]. However, in a project-oriented approach, the aim is to build a common repository for all consortium members, which focuses on a certain scope and aim of the project. In contrast to the approaches seeking for a complete and generic alignment, we propose to master the heterogeneity derived from business reference models, which are partially applied. We therefore propose to seek neither to modify the structure of one of the repositories nor to merge them. We create a new version V_{i+1} of a given business repository V_i considered as Reference Repository by adding some elements or some semantic relationships from a second business repository "A", depending on the level of granularity or consistency.

We applied this methodology in our case study with MES business repository IEC/ISO 62264, which has been enriched by the Supply Chain Operation Reference (SCOR) model. We then implemented it the ARIS SOA Architect platform.

The remainder of this paper is organized as follows. Section 2 introduces the literature review in terms of techniques and approaches related to enterprise modelling, business repositories and systems' interoperability. The alignment methodology, the enrichment process, and its implementation are presented in Section 3. In Section 4, we evaluate the methodology using an Enterprise Architecture Maturity Model based on a set of practices. Finally, we draw some conclusions for firms and outline some directions for future research, in Section 5.

2. Literature review

Most information systems (IS) contain several applications to meet several business needs, According to Refs. [3] and [6], the main characteristics of a company's applications are autonomy, distribution and heterogeneity. There are various levels of heterogeneity, including technical, syntactic and semantic. In this paper, we focus on the problems of heterogeneity of enterprise applications, particularly at the semantic level, which is one of the major problems in any interoperability and/or integration process. According to the European Interoperability Framework [7], there are three aspects of interoperability: (i) organizational, (ii) technical, and (iii) semantic. The different aspects of interoperability emphasize the fact that the heterogeneity of IS in data, applications or process levels makes the implementation of interoperability between IS more difficult. This complexity creates new strategies, methods and architectures for the design of IS to be qualified as interoperable.

After an introduction on the alignment issue and a brief survey on enterprise modelling and modelling frameworks, the remainder of this section presents the two main repositories that form the basis of this research work, the IEC/ISO 62264 repository and the SCOR model.

2.1. Interoperability vs alignment

This issue of interoperability and heterogeneity is crucial for MES when manufacturing resources, processes, and control methods are heterogeneous. The Manufacturing Enterprise Solutions Association proposes a formal definition [8]. MES is one of the software solutions used to bridge production planning and equipment control systems. To meet the needs of a variety of manufacturing environments, they identified 11 main functions, some directly linked to the process, and others described as cross functions.

The academic research on integration problems points out the importance of the integration with other information systems. Ref. [9] propose a service-oriented framework to address reconfigurability required by changing business environments. Ref. [10] present a literature review of MES systems, showing several considerations on commercial solutions, and major issues related to their use and implementation. These authors report on in-depth discussions on the research areas that would have to be explored in order to resolve the increased complexity of MES systems.

A well-known business standard for MES is the ISA-95 standard published by the Instrumentation, Systems & Automation (ISA) Committee. An academic version has been published as the IEC/ISO 62264. This standard deals with the formalization of exchange, around the manufacturing system, with other areas of the company. Its function model puts the manufacturing control function in a central position, intermediary between the various departments of the company. ISA-95 is widely adopted by market players for the design of information flows between shop floor applications and those at a higher level. It also allows the industry to have a consistent terminology. MES are used, inter alia, by the aerospace, automotive, semiconductor, optoelectronic, pharmaceutical and petrochemical industries [11–13,41].

Both MESA and ISA organizations highlight the diversity of software capabilities required, with software packages covering different manufacturing domains that often overlap. Semantic alignment is then a major challenge for MES projects for companies.