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New perspectives for the future interoperable enterprise systems

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ABSTRACT

The rapid changes in today's socio-economic and technological environment in which the enterprises operate necessitate the identification of new requirements that address both theoretical and practical aspects of the Enterprise Information Systems (EIS). Such an evolving environment contributes to both the process and the system complexity which cannot be handled by the traditional architectures. The constant pressure of requirements for more data, more collaboration and more flexibility motivates us to discuss about the concept of Next Generation EIS (NG EIS) which is federated, omnipresent, model-driven, open, reconfigurable and aware. All these properties imply that the future enterprise system is inherently interoperable. This position paper presents the discussion that spans several research challenges of future interoperable enterprise systems, specialized from the existing general research priorities and directions of IFAC Technical Committee 5.3,[1] namely: context-aware systems, semantic interoperability, cyber-physical systems, cloud-based systems and interoperability assessment.

1. Introduction

Increasing diversity of the environment in which enterprises are collaborating with its customers and suppliers has established interoperability as a scientific challenge of major importance. The need to address this challenge becomes even more important when considering that new paradigms such as Internet of Things and cyber-physical systems have introduced new identifiable resources with communication and processing capability and have contributed to significantly increased complexity of the technical environment in which above mentioned collaborations take place.

Although industry has responded to the interoperability challenges with the development of collaboration interfaces and integration mechanisms, such development may become unsustainable with the rapid growth in the variety of system architectures. The traditional approaches to achieve interoperability have targeted facilitating negotiation between systems to enable meaningful and purposeful interoperations. When this negotiation is carried out in processes where two systems attempt to understand each other's interfaces, then capability to interoperate is dependent on its "capability to understand". This consideration can be extended to include the capability to understand various types of stimulus or data from a (including raw data, perceived physical phenomenon, a message from another system or a social media event).

The need for continued research in Enterprise Integration and Interoperability has to be underscored along with identifying the developing trends and issues of relevance to the broader domain of Enterprise Information Systems (EIS). It is important to recapitulate

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[1] IFAC Technical Committee 5.3 « Enterprise Integration and Networking », http://www.ifac-tc53.org

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the Grand Challenges defined in [1], which are still valid. This earlier identification of Grand Challenges emphasized the importance of Collaborative Networked Organizations, the adoption of Enterprise Modelling techniques and Reference Models (while emphasizing model reuse), the importance of addressing Enterprise and Process Models Interoperability, the need to develop methods to support Verification, Validation, Qualification and Accreditation of Enterprise Models.

It is also important to note that recent advances in information and communication technologies (ICT) have allowed enterprises to move from highly data-driven environments to a more cooperative information/knowledge-driven environment [2]. The supervision, monitoring, adaptation and control of the enterprise systems dynamics and of the eco-system of network(s) they are operating are the requirements that guide the design of an effective management framework. This is especially true when recognizing the fact that new ICT governance models will continue to emerge; this in turn will lead to continued evolution of their information systems and infrastructure accordingly [3].

According to [4], while first generation EIS were application-centric with not necessarily integrated business rules, second generation EIS can be considered to be data-centric and driven by the integrated databases. Third generation EIS focus on business processes with appropriate process management architectures, supported by integrated systems. Fourth generation EISs (current one) are human-centric and they are driven by new human-machine interfaces, with challenges for standards, security, transparency of control, user simplicity, rights management, IT and business working in a cooperative environment. According to authors, fifth generation EIS (emerging) can be considered things-centric and driven by the digitalisation and integration of "things" into a cyber-physical environment, with challenges for interfaces and communication platforms as well as service-oriented architectures. Then, next-generation EIS (NG EIS) can be considered everything-centric and driven by creating interplay networks of people, data, things and services, with challenges for achieving secure openness and capability to interoperate of and with all entities (Table 1).

The properties of these future NG EISs have been identified based on the synthesis of the different works, mainly done within Future Internet Enterprise Systems (FInES) cluster of projects, supported by the European Commission. In its recently published research roadmap (FInES, b), FInES cluster identified the ICT solutions and socio-technical systems aimed at supporting the emerging future enterprises that will largely operate over the Future Internet, including also enabling technologies. The following properties of NG EIS are identified:

Omnipresence: Omnipresence refers to being present everywhere. In an EIS context, this refers to the implementation or existence of EIS on a wide range of computing and other platforms. Traditionally, EIS have been implemented on networked computers and the web for various application contexts. Recently, the advent of 'thin clients' such as tablets, smart phones, smart watches and other devices has provided the basis for the continued evolution of deployment scenarios for next generation information systems. As the computing power of these thin clients and devices increase, EIS' can be run on such clients (through cloud or other technologies) as well can be implemented through integrating an array of distributed components deployed from various locations in the world.

Model-driven architecture: The behaviour of Next Generation Systems will be driven by advanced information based models (from distributed locations) which can control the functionality of the corresponding collaborative enterprises; this can radically influence the accomplishment of a given product development life-cycle or any other non-engineering activity or set of activities. For these reasons, the architectures of such systems can be described as being 'model-driven'. By adopting a different model or modifying an existing model, the functional behaviour of a given enterprise can be modified (or 'controlled' to address changing customer, environment, industry or other requirements.

Openness: In the EIS context, 'openness' typically refers to technological (and legal) accessibility of software entities, artefacts and distributed collaborative processes based on knowledge sharing between peers. In broader contexts, openness can also refer to transparent organisational structures. Such practices can include 'Internal openness', 'external openness' or a hybrid combination of both. Internally, technologies to support such openness can include co-creation environments and tools within the daily functioning of an organization. Externally, openness can include adoption of crowdsourcing, and open innovation market based approaches. Such characteristics will dramatically impact both inter-organisational and intra-organisational ways to creating new products and processes while providing robust support to

Table 1
Enterprise information systems generations (extended from [4]).

EIS Generation	1 Application centric	2 Data centric	3 Process centric	4 Human centric	5 Things centric	6 Everything centric
Timeline	Around 80's	Around 90's	Around 00's	Around 10's	Around 15's	Around 20's
Iconic technology	MRP	ERP	BPM	HMI	Sensors	Devices
Technology drivers	Databases	Dbms, client-server architecture	Internet, soa	Semantic networks, intelligent social media, Cloud computing, Virtual and augmented reality	Smart things, wireless sensor networks, Big data, Service science, cloud computing	Real plug and play systems, open and trusted Platforms, trustworthy infrastructures, interoperability service utility
Deployment environment	Local systems		Digital systems		Cyber-physical systems	
Business challenge	Efficacy	Efficiency	Effectiveness	Resilience	Sensitiveness	Proactiveness
Organisational challenge	Support of departments	Support of enterprises	Support of supply chains	Support of social networks	Support of sensor networks	Support of interplay networks
Technology challenge	Systems integration		Systems interoperability			
Knowledge challenge	Structured data	Integrated data	Dynamic data	Real-time data		Inferred data