An Isomorphic Architecture for Enterprise Information Systems Integration

Mingxin Gan[†], Lily Sun[*], Botang Han[†]

[†]School of Management and Economics
Beijing Institute of Technology, China

[*]Informatics Research Centre
The University of Reading, UK

Abstract. Enterprise information systems often face difficulties in linking various components and external systems. Interoperability among collaborating participants is hard to tackle in both business and IT domains. These call for effective architectural solutions that coordinate powerful technologies with business applications to enable seamless inter-organizational integration. The inter-organizational integration of information systems needs to be considered from an architectural point of view on issues around business, organization and information technology. In this paper, an isomorphic architecture for systems integration (IASI) is proposed with a focus on supply chain management systems. This architecture allows integrating the business agility and IT infrastructure by consolidating processes between these two domains, and facilitates business changes with simultaneous evolution of the IT infrastructure.

1 Introduction

The supply chain is based on an integrative philosophy to manage the total flow of a channel from the earliest supplier of raw materials to the ultimate customer and beyond, including the disposal process [3]. So a number of functions are needed to be integrated into the total process throughout the supply chain to support the management of inter-organizational business. The effort of integration has been propelled and driven by the rapid development of information technology (IT) and information system (IS).

Workflows and different software components have been developed independently and changed over time. Information systems integration focuses on the inter-organizational linkages of different systems. The integration is achieved through architecture so that the overall system continuously provides useful information

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services to the organization within which it functions. In the IT domain, information systems architecture represents the structure of the components, their relationships, principles and directives with the main purpose of supporting business as well as its integration.

Normally, an integrated architecture can be divided into three levels: *information (or data) architecture* which describes main data types required by business operators; *application architecture* which defines applications needed for data management and business support; *and technological architecture* which represents the main technologies used in applications implementation and the infrastructures that provide an environment for IS deployment. Structural coherence in the architecture can be achieved through the adoption of common data, process and technology definitions [6].

Integration architecture provides a generic framework for information exchange and coordination among a variety of existing software systems [12]. In this sense, an information system architecture can be divided into four levels in a horizontal integration. *Communication services* such as Communication Standards (ISO/OSI-layers 4-7) are required for inter-process integration to ensure that all aspects of the communication are identical among systems. S*yntax* which is a data level integration such as EDIFACT and ANSI is required to define the order, length and the type of data being exchanged. But it is not sufficient for an automated integration of system. *Semantics* as object level integration such as EAN and D&B is needed to assign real world subjects and notions to the transmitted characters. *Pragmatics* as process level integration (workflows etc.) is a feature of sophisticated workflow systems which makes sure that not only transmitted data has been understood but that subsequent actions are triggered in an integrated system.

To motivate the need for enterprise information systems integration in a supply chain environment, an Isomorphic Architecture for System Integration (IASI) based on Model Driven Architecture (MDA) is examined. IASI is described to address the issues of inter-organizational integration between domains of IT and business based on a convergent architecture, which can help produce a flexible, well-structured integrated system with coherence.

The rest of the paper is structured as follows. Section 2 presents the MDA-based architecture called convergent architecture (CA), Section 3 describes the IASI built for integrated enterprise information systems based on CA, Section 4 concludes the paper with discussion on directions for future research.

2 The Architectures for Information System Integration

2.1 Related Work

Although an inter-organizational infrastructure is important to enable flexible supply chains and theory to guide its development [18], research on the details of structuring inter-organizational relations and infrastructure has not been given due attention [17].

Methods and tools have been introduced to address the issues for integration such as CoopWARE integration architecture [12], Distributed Processing Architecture [1],

Integration Infrastructure [19], Horizontal Integration [7], EAI-architecture [14], Enterprise Integration Architecture [8], B2B Integration [11], and the method of Robert Bosch Group [13]. Although these architectures as well as methods succeed in IT domain by giving an IT infrastructure to facility the integrated architecture, the consolidated linkage with business domain has not been reached well. Most of the practices in supply chain integration focus on the inter-organizational linkages triggered by IT infrastructure from technology point of view since the role of the IT infrastructure in responding to and shaping business options with agility is recognized as critical [15];[10].

However, most of these methods pay a great deal of attentions on a single level of integration separately. These practices bring concept divergence to the dynamic supply chain integration, although they can bring the idea of collaboration and integration technology into enterprises. When change happens either in business domain or IT domain especially in the various collaboration settings, one has to face difficulties to match the other.

Most designs of information systems for integration have not been deployed well in an integrated manner, which leads to an unmatched phenomenon called concept divergence in domains. Many advantages of leading technologies are therefore sacrificed. Consequently this phenomenon will be magnified when changes occur continuously in business domain particularly in a dynamic supply chain environment. As we know, a small divergence in a static condition will become larger in a dynamic condition. This phenomenon will be magnified in inter-organizational integrated information systems. Business in such a complex environment will be not only dynamic but also expands from an individual enterprise to inter-organizational. Thus the development and maintenance of such information systems will face much more difficulties to cope with the change of the businesses especially when enterprises collaborate with others. So Information systems among enterprises need to be integrated well to support collaborative business. Information system architectures in supply chain integration therefore need to focus on the relationship between IT and business domains in an individual enterprise as well as in inter-organizational connections.

2.2 Convergent Architecture

Model Driven Architecture (MDA) is a standardization initiative and architectural direction of the OMG (Object Management Group). It offers a full life cycle approach for solving the problems of developing, deploying and integrating existing distributed systems. Emerging technology, assembling virtual enterprises can therefore span multiple companies and implementing business intelligence solutions and enterprise information portals in a multi-vendor environment. Technology projection is a feature of an MDA-centric approach as well as an IT-architectural style which transforms a model to another model or as a final step, maps a model to an executable system infrastructure.

Convergent engineering (CE) is introduced by Taylor (1995) as a design vision with a methodology which aligns business and IT systems through a set of design patterns and design techniques based on the object paradigm. Convergent architecture (CA) is a MDA-based IT-architectural style which leverages the benefits of agile development and convergent engineering in practice as well as signifies the alignment of business

and IT model into one common, synchronized model and takes a holistic approach to project, business and system design. CA provides a practical, architecture driven MDA process and techniques enabling business and software design to become a consolidated effort. The key technologies and theories are as follows [9]:

- Three pillars of the holistic architecture are defined in the MDA-oriented convergent architecture being concerned with simplifying the development of effective IT systems by achieving synergies with each other: business design; project design which defines how to achieve project design using modern modeling and convergence techniques; and system design which defines how to achieve system design using MDA techniques.
- RASC (reduced abstraction set computing) represents the core component abstractions and corresponding architectural layers to achieve the goals of convergent engineering, through which the three pillars of the holistic architecture are consolidated together. As an example of RASC, OPR (organization, process and resource) are the three core abstraction of RASC and are verified to be the minimum sets of the formal structural components through which the business model can be transformed to IT system.

This solution leads design of different systems to a synchronized process as well as isomorphic concepts structures to avoid the divergence in systems. Systems which are designed using the concepts of CE are supposed to be understandable, maintainable and easily modified in response to the changing business conditions.

2.3 Problems and Challenges

Systems designed using CA will face difficulties in a supply chain in inter-organizational collaboration where business changes are not only inside an enterprise but also expand to inter-organizational scope. These information systems are designed as a logic structure using CA in one enterprise. They have to change to meet the need of new business which is controlled by more than one enterprise. They will also face continuous changes under a more complex environment. Thus, the logic structure will be brought an inconsistency into the inter-organizational system. IT infrastructure which mapped to business domain has to add new business logic components to the origin one. The reason is that isomorphic structure is not fully developed by CA for inter-organizational collaboration.

Practically supply chain processes are derived from integration of enterprise processes, so performances such as flexibility and agility will be derived from both internal enterprise and the connections between enterprises [5]. Both the intra-organizational and inter-organizational performances have close relationship with each other. The linkage between the single system and inter-organizational system has not been addressed effectively.

In a stable environment, an enterprise may have chosen to forge highly specific and efficient process linkages and information exchange mechanisms with select partners, but in the dynamic environment, enterprises need to develop more robust and reconfigurable linkages that can deal with changes in the business environment [4]. The most obvious difficulties in drawing an integrated architecture lie in two aspects as expansion of business which is the objective and the IT correspondence with the wider business. Furthermore, dynamic business causes the difficulties severe with which IT infrastructure faces challenges to cope with business.

3 Isomorphic Architecture for Inter-Organizational Information Systems Integration

3.1 The Components in Isomorphic Architecture

In an integrated architecture as described in Figure 1, highly specific and efficient process linkages and information exchange mechanisms are built for enterprise to propel and drive the collaboration with selected partners in a stable environment. Furthermore, more robust and reconfigurable linkages which can deal with changes in a dynamic business environment are explained through a method introduced in this architecture.

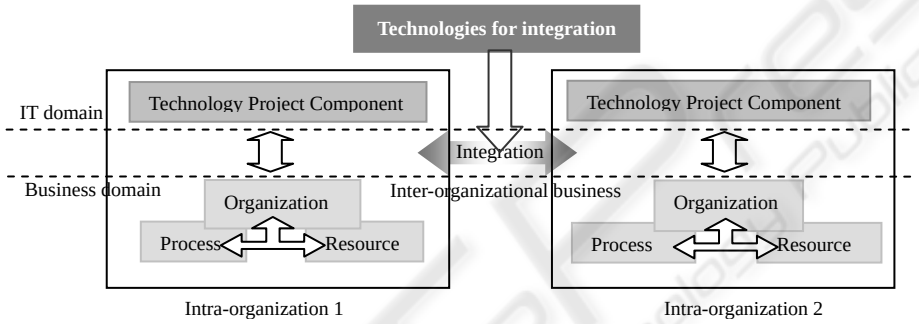

Fig. 1. Integration between business scopes in both business and IT domains

As the main design processes in information system development, business design and system design have responsibility to be illustrated with the correlation through a specific and coherent way to produce an IT system with rapidly tracking to business in a supply chain environment. Figure 1 also illustrates the modules in IASI and their relationship when organizations integrate. Each business scope in IASI indicates the scope of single organization before integrating. The component which is called technology project component above the upper broken line belongs to IT domain, which comes from the inspiration of MDA-centric approach and will be mapped to technologies as a certain component reflecting an IT-architectural style. And those below the other broken line belong to business domain, each of which individually represents the three key elements of OPR being a certain case got from RASC in CA. Here OPR is emphasized to explain the integrated architecture.

The arrow labeled as integration between the two broken lines as well as between business scopes shows how the business objects are mapped to IT domain when integration, whose realization will be explained in detail in Figure 2. The main proposed solution for the interaction between domains is shown in Figure 2, which illustrates the mapping between business and IT domains in inter-organizational integration.

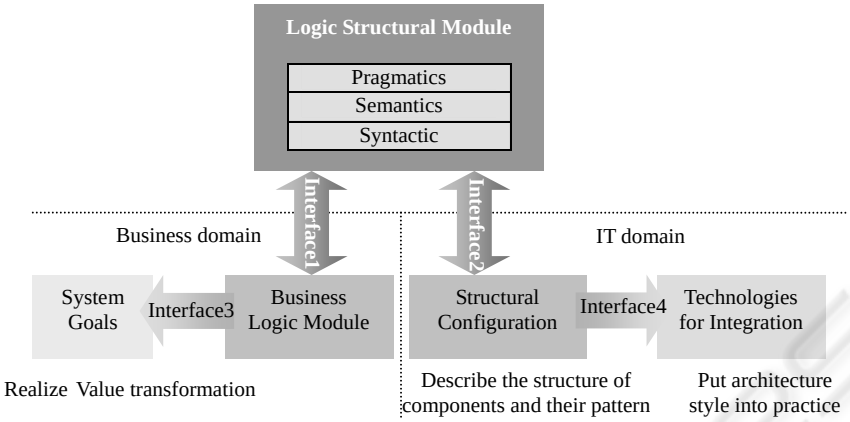

Fig. 2. Model for mapping business and IT domains in inter-organizational integration

Business integration happens at the overlap of the OPR. The arrowhead among OPR shows the reaction of these elements. When collaboration happens in supply chain, resources which will be mapped by technology projection component expand from one single enterprise to multi-organizational scope and obtain more dynamical characteristics than before. Processes in the enterprise will utilize and generate much more resources of the wider scope and extend into the suppliers and buyers with which enterprise is collaborating. The scope of organization is also different from before where enterprises cooperate to manage some core business processes and resources together.

While the integration in IT domain happens among technology project components and mapped to technologies for integration. Technologies supporting IASI to solve the challenge of integration in IT field function at different levels. XML substantially facilitates information exchange and real time distribution in an integrated supply chain and conveys specific display instructions as well as depicts a variety of file types. Middleware component technologies as CORBA, DCOM, Enterprise Java Beans make information to communicate effectively, lead the supply chain system to more scalable, compatible, standardized reusable and better equipped, regardless of platforms or programming languages. Semantic Web is for data standardized and machine processable; Web Services facilitates interoperability across platforms and languages as well as component technologies and as a framework delivers features to developers in a simple, reliable and scalable fashion so as to allow the interaction and collaboration at a service level.

3.2 Interoperability-An Architectural Interaction in Intra-Organization

Each intra-organisation should have the integrated architecture that would enable inter-organizational system having flexibility and agility. These performances come from intra-organization as well as inter-organization. So intra-organizational architecture should support the realization of the inter-organizational one not only by its own structure, but also by the interfaces it offers to link the external system. Thus every part of the single system also will have the ability to be agile and flexibility against the change with this structure.

Transaction loss comes from the rarely understanding of the mapping between the concepts in business analysis and IT solutions, although some practice is intended to assist with this problem by connecting these two different aspects of the system in a precise, automated way through integrating process, assets, and deliverables. As a whole logical structure, IASI has three layers as from pragmatics, semantics to syntactic according to the semantic point of view. Each layer describes its own logical relation separately.

Figure 2 illustrates five key modules in one enterprise system with integrated architecture style in IASI, which is the core processes of the integrated architecture and through which how business objects are mapped to IT configuration through logic structural module is described. The assumption that each module can be abstracted as sets of signs enables the functions of interfaces being regarded as transforming signs. The above module which is labelled as Logic Structural Module can help the signs in the modules follow a same structure to organize the relationship of signs within each one. Thus, whenever change happens in one context, others can correspond by following the new logic structural module which is always the first one to reflect the change. The definitions and interactions of them in IASI are as follows:

- *Logic structural module* which refers to the pattern how resources, processes and organizations are organized is considered as an important issue in architecture design. It is not only used for building close relationship with business domain through explaining, abstracting and refining the core business processes and corresponding resources in a logic way, but also affect the configuration of IT domain through the way how the business objects are mapped to technological components hierarchically. Thus it connects both of the domains together with a union logic structure and let components in both domains interact with each other. It also affects the performance such as flexibility of the whole system and the ability of tracking of IT significantly.

  There are three levels of realization for the logic structural module as: *Syntax* which refers to the data level integration which is required to define the order, length and type of data being exchanged; *Semantics* which refers to object level integration which is needed to assign real world subjects and notions to the transmitted characters; and *Pragmatics* as process level integration, which is a feature of sophisticated workflow system ensuring the understanding of transmitted data and the subsequent actions being triggered.

- *Business Logic Module* as normal objects that contain only business logic without having knowledge of any other layers as we know is the way of continual logical process in an organization, which will obtain logic inspiration from Logic Structural Module and also communicate with it. Thus it can be

described by the module called Structural Configuration in IT domain through Logic Structural Module and realizes System Goals Module through interface3 which is the value transformation process.

- *Structural configuration* describes the structure of IT components and their communication patterns. It comes from the Logic Structural Module and gives inspiration to the module as well. Architecture style can be obtained through abstracting from this module.
- *Technologies for integration* refer to the leading technologies which will realize the architecture style as well as integration as a whole. *System Goals* describe the business goals of an enterprise and further it will be extended to the alignment of supply chain partners. These two modules seem to belong to quite different fields in practical, but in this figure they can be linked together through being transformed by each interface to the same logic structure. It shows that the businesses domain and IT domain has close relationship with each other. Later, the detailed description of the four interfaces in IASI will be obtained, each of which represents a certain interchangeable process in different context by applying meta-model to map different models based on this figure.

4 Discussions and Future Work

An integration architecture called IASI is designed to support common features of collaboration among enterprises with the function of enabling different levels of flexibility, isomorphic structure and process integration. In IASI, concept isomorphic not only needs to be realized in an individual enterprise, but also in an integrated architecture for multi-organizations to obtain the seamless integration among them.

In IASI, interoperability is gained by the utilization of logic organizational way module. When collaboration happens among partners, this module will be changed to a new structure. For example, when procurement happens between manufacturer and supplier, the module which is a whole logic picture in manufacturer will be changed to a new one with a linkage as the input process from the supplier. Consequently the business processes will be added to some new processes as parts of them while the structural configuration in IT domain will also expand to a wider scope, although some technologies can realize the collaboration on different platform. If the architecture of one enterprise is built as IASI described, the collaboration will be obtained with more flexibility and reliability. Thus the seamless integration is achieved easily.

The change of organization, process and resource in a single enterprise as well as in an inter-organizational scope means combining new pieces of structures to the original structure. When the whole structure is isomorphic, the new information in the three elements will become an isomorphic structure as well and obtain new place easily in the original one. At the same time the whole structure won't be broken into pieces without logic with IASI.

The ideal situation is that the enterprises have got an isomorphic structure with OPR before their collaboration so that their architectures needn't be abstracted and arranged from different disorder structures to an isomorphic one. In further work, some agents with different functions enabling the agents to transfer their different isomorphic structures will be introduced into one generic isomorphic structure.

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