Is system of systems a candidate rationale artifact for entreprise information-intensive system modeling?

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IS SYSTEM OF SYSTEMS A CANDIDATE RATIONALE ARTIFACT FOR ENTERPRISE INFORMATION-INTENSIVE SYSTEM MODELING?

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Abstract:

Engineering an enterprise system as a whole from business to manufacturing to fulfill capabilities in order to achieve global performances remains in fine a complex ad hoc process. This complexity is addressed by many modeling artifacts ranging from top down enterprise modeling frameworks to bottom up COTS systems engineering approaches. Increasing manufacturing globalization and enterprises collaboration are impacting this large-scale systems integration, so that the SoS paradigm is challenging both academic and industrial communities to border the whole enterprise system for any new mission on the enterprises operational components. This paper addresses some system thinking issues about SoS as a candidate rationale artifact for enterprise information-intensive system modeling.

Keywords: Large-scale systems integration, system of systems, emergence, systems engineering.

1. INTRODUCTION

Engineering an enterprise system as a whole from business to manufacturing to fulfill capabilities in order to achieve global performances remains in fine a complex ad hoc process. This complexity is addressed by many modeling approaches to order information [6] for improving integration and interoperability of information-intensive components systems within the entire networked enterprise. Results of these approaches can take many forms and depend on modeling artifacts used to design enterprise systems and components as a coherent whole regarding their competitive environments. Nevertheless, new business trends as multi-enterprise collaboration [21] require for designers to include paradigms such as large-scale systems integration (LSSI) one in their modeling processes to design complex large scale enterprise systems. To that end, systems engineering (SE) establishes practices to support different skills and abilities to engineer these complex systems as a whole of heterogeneous and autonomous information-intensive components systems. But the ability to tackle these systems is strongly related to artifacts on which designers base their modeling rationales. This concern is addressed by both research and engineering works and led to new concept as system of systems and to principles inherent to the notion of complexity as emergence one.

In section 2, trends and issues of both the academic enterprise modeling approach and the engineering modeling in enterprise approach are presented. These two approaches are compared in regards with rationales they are based on. Section 3 argues that bot-top (bottom-up and top-down) rationale and system of systems (SoS) are respectively an approach and a candidate artifact to strengthen the notion of system when designing a complex system as a whole enterprise system of information intensive components systems. Section 4 stresses that emergence is a principle to be tackled in order to apply bot-top approaches and their related artifact to design an enterprise system as a whole from business to manufacturing. This paper finally underlines the perspective of SoS as a rationale artifact for enterprise systems modeling issues.

2. ENTERPRISE MODELING ARTIFACTS VS MODELING IN ENTERPRISE ARTIFACTS

Enterprise Integration (EI) is related to the organizational chart of elements and relations of an enterprise system in order to perform it as a whole to achieve in an efficient way the business goals. As a pre-requisite of EI, modeling approaches are merely "top down" to ordering information in a pre-determined whole of enterprise or merely "bottom up" to ordering information in wholes merging for each new enterprise projects.

Enterprise modeling (EM) is a top down approach for designing an enterprise system from reference and standardized modeling frameworks. It rationale artifact is a goal-seeking model to interface the real-world enterprise system with the intensive information components systems. The modeling process consists in projecting a model of the enterprise activities on a technical architecture throughout the model of the business functions which could be automated by taken into account the interoperability capabilities of the existing components which should be integrated. Various methods and modeling techniques based on systemics and/or object-oriented rationales [25][30] are concerned by this modeling process and describe different aspects of enterprise systems as an explicit set of ordered information. To achieve this description, most of the efforts are now directed towards interoperability between modeling tools to provide enterprise systems oriented generic constructs [27] as a language to bind multi-part modeling standards together. In this perspective, enterprise modeling approach is a well suited approach for model large scale project systems to unfold their operational structures that realize the required function.

Modeling in Enterprise (ME) is a bottom up approach to integrate at a technical level intensive information components systems as timely wholes of ordered information from the de-facto standards and related engineering methodologies of components offered by software or hardware vendors. It rationale artifact is a solution-seeking COTS to implement problem-solving components with business processes to achieve local performances as required by business goals. The modeling process consists in matching the business processes to the corresponding components systems throughout their configurations to suit the organization needs. Achieving the implementation of components within the whole enterprise system depends of the capability of components to be interoperable in order in the end to operate together. Thus, most of the efforts of software and hardware vendors concern the standardization of their components in order to facilitate their integration in the entire enterprise network. This bottom-up approach is pragmatically adapted to solve practical issues for each new enterprise project within the agile business context and creates the new local organization that satisfy the required business goals.

Both approaches substitute enterprise systems for modeling artifacts in order to simplify the complexity of their description as wholes. The results of these modeling processes are plants [20] and enterprises wide puzzles built with generic modeling constructs or standardized components. Information is considered as the key element to glue the different multi part models or the components within the whole operational architecture of an enterprise system. However, in an EI perspective, this has an impact of improving the performance of enterprise system when incorporating new functions or new components onto the enterprise system : the impact of each extension of the puzzle on the entire enterprise system is not so clear. Balancing practical issues between these modeling approaches is to design the whole information-intensive enterprise system throughout an explicit model of a system as a 'lego' here new or existing functions and components can be assembled for any business requirements.

3. SYSTEM OF SYSTEMS RELATED RATIONALE ARTIFACT OF MODELING APPROACHES

Improving the design of an enterprise system as a whole with a bot-top modeling approach consists in to seek jointly to have information-intensive components systems arranged together into an operational assembly and to create the entire enterprise system by using business functions to direct their assembly. This large scale enterprise integration is related to the organizational chart of components at a micro level and enterprise system at a macro level to fulfill new capabilities to achieve enterprise systems global performances. Components and functions are able of collaboration so that a major of their efforts is spent to operate independently for their own purposes and an other part creates capabilities to adapt to each other to achieve the given goal of their collaboration.

Bot-top approaches appears as more suitable to dynamically model enterprise systems as a whole [26][12] even if they include complex notions as evolutionary computation, self-organization or if they exceed mental capabilities of designers [28] when considering the complexity to master together elements of a system. To cope with this complexity, a SoS could be noted as a candidate rationale artifact to bring consistency of the notion of systems which fails to previous modeling approaches. SoS is a concept at the core of research and development works to study the structure and dynamics of large scale collaboration between enterprise systems. SoS includes collaboration through the notion of interoperation [9] combining components to build an enterprise system as a lego and going beyond the notion of integration and interoperability which force interactions between components to form an unified enterprise as a puzzle. A SoS can be defined as a complex of elements at a micro level with capabilities to participate to the mission of the SoS, at a macro level. Five properties characterize an SoS [15] :

- Operational independence and managerial independence are two mandatory properties for SoS autonomy to maintain their independence with the whole.
- Evolutionary development is a property of both components and composite whole that must be explicitly recognized from a global perspective in order to manage the impact of evolution of each autonomous components of a SoS.
- Geographic distribution is a property to facilitate the efficiency of the three first properties by encouraging a SoS as a networked structure of components.
- Emergent behavior is related to the fact that the SoS have to perform new functions to achieve its given missions that do not reside in any components.

In advance of the acceptance of SoS as an rationale artifact of bot-top approaches, we have explored this promising artifact on some industrial case studies for enterprise information-intensive system modeling issues. Our study focuses on four enterprises aware of enterprise integration issues and in particular on one company which is distributed among seven autonomous groups, each one having its own information intensive components systems to manage and to operate its processes. To respond to requirements of products traceability, this company spend most of its efforts to improving interrelations between groups in order to make them interoperate as a coherent whole. As shown in the following table, the new organization that takes place in the company responds to the properties of a SoS even if a lack of interoperability between components has an impact on the control of the emergent behavior resulting from the overall interactions between components.

	System of systems properties [15]				
	Operational independence	Managerial independence	Evolutionary development	Geographic distribution	Emergent behavior
Company A	Each group has their own information intensive components systems.	Each group is managed by a staff to decide on the choice of information intensive components systems.	Company development is evolutionary with functions and components added, removed and modified by groups.	The seven groups are distributed on different sites with communication capabilities to exchange information	The capability to face economic challenges depends of its behavior which emerges from the interactions between groups.

Table

This operational management issue is considered as key point for the development of enterprise systems in a large scale systems integration perspective. Therefore, solutions have already been proposed [4][10] to reduced the emergence risk in order to master the complexity of management of complex large scale systems. But, as underlined by [9], it is necessary to recognize the importance of emergent effects in determining the global characteristics of complex enterprise systems to manage and to operate them in an efficient way with regards to the mission assigned to the collaboration between their components.

In the next section, emergence perspective for SoS bot-top modeling approaches is discussed.

4. EMERGENCE RELATED MODELING APPROACH OF SYSTEM OF SYSTEMS

Emergent behavior is used to describe a feature of a complex system and is related to the emergence principle that creates a functional separation between components and their interactions at a micro level and their collective behavior as a whole system at a macro level. Different varieties of emergence are identified [5] and in general, emergence refer to properties of a system that can not be captured by the properties of the parts. Emergence principle is addressed in most cases by scientific works but it arouses progressively interest of engineers to solve practical issues of designing complex enterprises systems [13][31]. Among works concerned by emergence, there is a general agreement to consider the classification proposed by [23][2] as a sort of metrics to characterize different types of emergence : weak emergence is related to behaviors at a macro level which is caused by properties of underlying systems and refers to complex systems described in terms of their parts; strong emergence describes new system properties arising exclusively at a collective level or in the relationship of the system with its environment without any relationship between the system and its parts. Under particular conditions, this form of emergence can be formalized through mathematical theories in order to be concerned by a scientific meaningful [1]; nominal emergence [2] completes these two types of emergence to clearly distinguish the interdependence between arisen properties and properties at a micro-level. In [3], a form of metrics of processes by which systems display emergence characteristics is proposed. This metrics identifies processes by the type of emergence they generated : computational emergence is the result, within the same scientific frameworks, of a computational process from local determinist and computational interactions between elements of a system; thermodynamic emergence results, within different scientific frameworks, from non determinist processes at a micro level; Finally, the emergence relative to a model is related to situations where observers need to change their predictive models to observe the new feature arising from interactions at a lower level.

Talking about emergent behavior in a system of system refers, at our opinion, to weak emergence when considering definitions and properties characterizing a SoS. Furthermore, we argue that emergent behavior in a SoS can be described by both a computational process and by a relative to a model one to provide a formal modeling framework and a modeling approach to tackle emergence phenomenon when engineering an enterprise system as a SoS. In a general manner, emergence principle is concerned by several approaches and techniques that support these processes. For examples, multi-agent systems [29][14] or cellular automata [32][8] are approaches close to our concerns and are used to dynamically model complex systems and their associated phenomenon. We can cite also the contribution of biological approaches to model complex engineered networks [24]. At last, emergent synthesis [26] is a very relevant approach to describe emergent behavior in a SoS. This approach harmonizes both bottom up and top down approaches to describe the global behavior of a system formed through interactions between its components and to verify the emerging global order and to modify it by rendering the global purpose to components. This approach has been in particular apply [18] to complex adaptive systems (CAS) to model the emergent structured collective behavior exhibited by CAS.

Our previous and current works are another way to tackle the emergence in enterprise systems described in terms of their information intensive components systems. To put into practice the modeling of an enterprise system by emergence, we have proposed [16][19] to include this principle throughout two information technologies based mechanisms : the 'nesting' mechanism (figure) of Object Role Modeling method [11] or the 'association class' of the Unified Modeling Language. Nevertheless, these mechanisms are not fully compliant with more theoretical (formal) definitions of emergent behavior within SoS. To making up this lack of formal framework, we propose [17] to use the promising Category Theory (CT) approach [22][7] to verify the coherence between together a composite whole, its components and the emergent behavior. The collective link and the colimit are the CT principles to describe the emergent behavior in a SoS. Our objective is now to extend these principles to bot-top approaches in order to provide a modeling framework and a modeling artifact for systems engineering when designing an enterprise systems as a SoS.

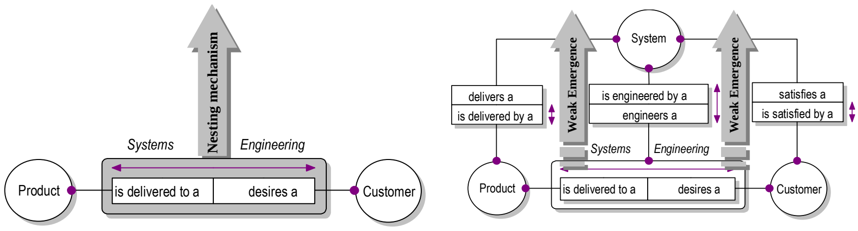

Fig. : Weak emergence related mechanism

5. CONCLUSIONS

SoS is intensively challenging both the academic and industrial communities in order to found the engineering of complex systems with more system thinking and bot-top approaches. The main expected result is to design a next generation of COTS with more capabilities to compose SoS as an emergent whole from existing systems when operating.

SoS should be a candidate rationale artifact for information-intensive enterprise modeling to take benefit of the huge of software packages operating in isolation when new missions have to be addressed as for collaboration issues.

Despite current research works proposing capability frameworks based on Maier's SoS properties for SE issues, a long way should challenge the systems sciences community to formalize each of these properties within an unified framework to make SoS an enterprise modeling rationale artifact.

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