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Modeling frameworks, methods and languages for computerizing Small and Medium-sized Enterprises: review and proposal

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Abstract. Small and Medium-sized Enterprises (SMEs) often lack of time, means and competences to define methodologically their requirements for a new software development. This creates a gap between the real needs and the system requirements identified by analysts and designers. It is thereby important to provide SMEs' stakeholders means to autonomously build and share knowledge about their organization. In this work, we present an analysis of a set of modeling frameworks, methods and modeling languages to identify these requirements in the case of such organizations. Taking into consideration unexpected limitations given by this analysis, we propose first an enrichment of the ISO19439 and ISO19440 standards to be applicable to SME typed organisations and second a requirements elicitation and validation process that is compliant with this new framework.

Keywords: Enterprise modeling, Requirements engineering, Design verification, Software system for SMEs

1 Introduction

When compared with large enterprises, Small and Medium-sized Enterprises (SMEs) usually have a simpler structure with limited sets of human, financial, and physical resources. Various Information System (IS) studies have focused on SMEs since the introduction of micro-computers in the early 80s [1] and showed their lack of IS competences and strategic vision. Moreover, SMEs still find difficulties in selecting application packages, or specifying their needs and wishes in the development of new software to support their activity. This is due to their low IS expertise, and their lack of time and means to get works owner support. This induces difficulty for the analysts and engineers when performing software requirements elicitation and validation activities.

Requirements engineering (RE) constitutes the earliest, most crucial phase of any engineering project and by evidence a software development project. It aims at bridging the gap between SMEs' stakeholders (business experts, decision makers and end users) and the designers and developers team in charge of building here a (set of) software application(s). It aims first to allow end users to describe as simply and as formally as possible their needs. It aims then to translate and provide a well-written, verified and validated set of requirement specifications to the developers. More precisely, RE is the branch of system engineering concerned with the elicitation, documentation and assessment of: (i) user requirements that represent the needs, wishes and conditions expressed by end users regarding the new system and reflecting the problem world and (ii) system requirements that represent the properties of the system, which constrain the conception of the solution. They are written by analysts and requirements engineers to meet the user requirements. The set of requirements is then considered as the foundation for a contractual agreement. The quality of the RE activities in the SMEs' software development project is often mitigated owing to: (i) The lack of well-established business procedures and practices, which induces difficulties in formulating and justifying the needs; (ii) The involvement of different stakeholders who have different cultures, vocabularies, concerns and may have conflicting points of view; (iii) The lack of formalization as SMEs' stakeholders express ambiguous and informal requirements, thus hard to verify and validate. These issues have raised a crucial need for providing SMEs' stakeholders assistance in formalizing their business and formulating their needs in a simple yet formal way. This work is therefore concerned with providing SMEs' stakeholders the means to: (i) autonomously specify their needs, build and share a common understanding about the structure and the behavior of the SME into an enterprise model, to guide the software RE activities; (ii) check the consistency of the produced models and descriptions with a set of verification means and finally (iii) transfer them to the developers of the software vender side without loss of information and respecting model and data interoperability expectations.

This paper is structured as follows: in section 2, we introduce the motivation behind this work. Next, we present in the state of the art section relevant enterprise modeling frameworks and reference models and a set of requirements engineering languages (section 3). Then, we present our proposal for SMEs requirements elicitation and validation in section 4. Finally, we conclude the paper and address future works in section 5.

2 Statement

Once established and facing activity growth, many SMEs need to dispose of suitable and adapted software, designed around their business rather than having to follow structuring COTS packages [1]. SMEs must then be able to define appropriate business requirements to perform their computerization. But in the current RE practices, most SMEs' stakeholders do not have the skills to use the requirements elicitation tools and the requirements are gathered informally by developers [2,3]. This is error prone, because developers lack of knowledge regarding the business

domain. Besides, SMEs' stakeholders are directly concerned with the description, argumentation and final decision about their business and needs.

We consider that the SMEs' stakeholders have to be involved as active actors, as soon as possible during the requirements engineering activities. To do so, they should be provided with simple means, that require no special knowledge in modeling notations or IT skills, to autonomously specify their user requirements. It is also important for SMEs' stakeholders to communicate their vision of the organization to the designers and developers. In fact most SMEs have not defined their enterprise model i.e.: the way they manage their activities, the distribution the responsibilities in the organization and the stakeholders' roles, the processes in which they are involved and the information and resources they use. Many concerns have to be addressed, formalization with reference frameworks and methods is then needed to build the enterprise model. All stakeholders can then dispose of a common and non-ambiguous understanding of the SME and its environment.

In addition, the user requirements and enterprise models defined by SMEs' stakeholders have to be formal enough to allow verifying their consistency and if they are well-formed according to modeling and verification rules. There is hence a trade-off between the necessity of the SMEs stakeholders' autonomy that requires a simple formalism and a level of formalization that allows verification and simulation. The enterprise models along with the user requirements constitute the base upon which the works owner support analysts specify the system requirements that represent properties of the system and requirements that guide and constrain the construction of the solution by designers and developers. The gaps that may appear between the user and system requirements, due to absences and inconsistency have to be reduced by the application of a systematic engineering process and tooled support.

3 State of the art

Our work is about understanding and analyzing the structure and the behavior of SMEs to be able to define, verify and validate system requirements. It uses the business view of SMEs' stakeholders as an entry point for the construction of the enterprise specific model. It therefore falls within the fields of enterprise modeling and requirements engineering. In this section we first present enterprise modeling methods and frameworks that guide the construction of the enterprise model. Then we assess a set of requirements modeling languages according to certain criteria such as their accessibility and the verification techniques that are used. Because of size limits we do not address in this article model transformation methods.

3.1 Enterprise modeling methods and frameworks

In order to manage the inherent complexity of enterprise systems due to their socio-technical structural and behavioral characteristics, enterprise modeling methods, architectures and tools were developed and used in support of the life cycle engineering of complex and changing systems. Enterprise Modeling (EM) allows the construction of business models that formalizes all or part of the business in order

to understand or explain an existing situation or to achieve and validate a designed project [4]. A business model is thereby an inescapable and very useful means of communication among stakeholders. Several EM methods, languages, reference models, architectures and tools have been defined since the late 70s such as the CIM Open System Architecture (CIM-OSA) that has been developed for integration in manufacturing enterprises but is widely applicable to integration of any type of enterprises [5]. It uses well defined modeling constructs structured into four enterprise modeling views: function, information, resources and organization views. In the same way (ISO/DIS 19440) proposes constructs providing common semantics and enable the unification of models developed by different stakeholders [6]. The enterprise model view dimension enables the modeler and the user to filter their observations of the real world by emphasizing on aspects that are relevant to their particular interests and context. It also guaranties enterprise modeling principals [7] such as the separation enterprise behavior and enterprise functionalities which provides a flexible and scalable representation of the enterprise.

The Generalized Enterprise Reference Architecture and Methodology (GERAM) [8] takes into account the CIM-OSA four modeling views to organize and define the generic concepts that are required to enable the creation of enterprise models. The framework for enterprise modeling (ISO/DIS 19439) standard [9] took back part of the GERA modeling framework. It provides a unified conceptual basis for model-based enterprise engineering that enables consistency and interoperability of the various modeling methodologies and supporting tools. The framework structures the entities under consideration in terms of three dimensions: the enterprise model view, the enterprise model phase and levels of genericity.

Along with the constructs for enterprise modeling standard ISO19440, the framework for enterprise modeling standard ISO19439 can be considered as an operational state of the art framework to manage the modeling activities of an enterprise or an information system [10]. However, even if requirements definition is part of the enterprise model life-cycle phases, the standards do not offer any constructs to support, share and save information about requirements. Hence, no distinction is made between the concepts of the user and system requirements and this mitigates the validation of the solution.

3.2 Requirements Modeling languages

Considering the (ISO/DIS 19439) modeling framework model phase dimension, RE activities cover the three first phases: domain identification, concept definition and requirements definition. The business functionality in terms of business processes, enterprise activities, their inputs and outputs and the resources needed for their fulfillment are then described. Therefore, RE encompasses requirements in term of functionality, information, organization and resources. It is highly related to EM activities, especially when RE is oriented to software development and IS definition. However, RE is considered as an independent engineering process and discipline that relies on an iterative process [11] that comprises several activities: (i) domain analysis and elicitation where the existing system in which the software to be built is studied and user requirements are gathered, (ii) negotiation and agreement about the possible conflicts among stakeholder and alternative situa-

tions, (iii) specification and documentation where the requirements are formalized and (iv) verification and validation of the quality of the requirements.

RE considers the matching level between the identified system requirements and the needs that motivated the project as the main indicator of success for software development projects. It is also important to check the quality of single or sets of user's requirements and enterprise models. Verification and validation techniques are hence used in both RE and EM fields. The main means used by enterprise modeling methods to perform verification and validation [12] are: (i) the use of standards, reference architectures and models to reduce the errors with guided modeling and as a support for consistency analysis, (ii) human expertise to review the models according to predefined criteria, (iii) tests, simulation and process execution techniques and (iv) formal methods used with languages that have a mathematical basis. They are used for property expression and verification and formal reasoning to prove correctness, completeness and consistency of the specifications. A study about RE practices in different industrial sectors [13] identifies the use of advanced techniques to ensure correct requirements writing such as: the use of Natural Language Processing (NLP) to verify the lexical correctness of requirements and the use of requirements boilerplates [14] for guiding requirements writing and checking. The use of ontologies or a controlled natural language (a set of predefined terms which represent the domains of knowledge of an organization) coupled with NLP is a promising way to verify requirement consistency and detect missing and ambiguous requirements.

RE provides several methods and languages to guide and support the requirements elicitation, documentation and validation activities. We studied a set of languages and approaches that can be conducted upstream of detailed conception, namely: RDM (Requirement Definition Model) part of the CIM-OSA modeling process [15], goal oriented requirements languages: KAOS [16] and GRL (Goal-Oriented Requirement Language) [17], scenario oriented language UCM (Use Case Maps) [17] and URML (Unified Requirements Modeling language) [18] a high-level quality and functional system requirements language. We are not trying to make an inventory of the all languages proposed in the literature, but rather identify the information that should be addressed while collecting and modeling requirements, and assess their accessibility to SMEs' stakeholders. They can be classified according to:

The orientation and basic concept: this defines the way requirements are modeled and described, and aspects through which they are considered. Two main orientations can be distinguished in the literature [19] (i) scenario based requirements languages like UCM that describe pragmatic, behavioral interactions that end users have with the system to be able to achieve their tasks, and (ii) goal oriented requirements languages that focus on the intended properties of the system expressed by the stakeholders such as KAOS and GRL. Reasoning with goals for functional user requirement elicitation is not an easy task for SMEs' stakeholders. They are more likely to describe their daily activities rather than thinking about the motivation behind them.

The accessibility of the syntax which directly influences the target users of the language: the more detailed a requirement language is the less accessible it gets. Considering their syntax, all the studied languages are meant to be used by

experts (works owner support analysts, requirements engineers, designers, etc.). The languages use artefacts that require modeling competence; they so cannot be handled by SMEs' stakeholders without prior training. As we are aiming to allow SMEs' stakeholders autonomously express their needs, languages using very light modeling artefacts and Natural language (NL) [20,21] would be more appropriate. Languages that use NL do not cover all the modeling views. For instance SBVR [21] is mainly used for business rules specification and data description using a controlled NL; it is accordingly only suitable for informational modeling.

The verification and validation techniques that are used: the languages that we studied mainly use non-formal or semi-formal techniques for verification and validation. RDM and UCM use simulation to detect potentially undesirable interactions and behaviors among processes or scenarios. Only KAOS proposes formal reasoning to check the consistency and completeness of models by rewriting the specifications into a verifiable model based on a mathematical formalism.

The modeling views covered by the language and the kind of information represented: we consider here the four modeling views recommended by the ISO19440 standard. We gather in a user and system requirement view, specific concepts that allow user and system requirements and goals to be defined, chosen and argued about; such as: goal, obstacle, system requirement and expectation. We distinguish for each language the concepts that are likely to represent the same information as the concepts from the ISO19440 standard to identify the modeling views that the language covers.

The studied languages propose concepts to collect knowledge about the enterprise (*activity, resource...*) necessary to build the information system that will be supported by the desired system, the latter is also addressed by concepts that specify its properties and the way it interacts with the environment (*requirements, expectation...*). However, these concepts are defined and modeled differently from one language to another. For instance, an activity in RDM details the identified business processes and is defined by its inputs and outputs; whereas in KAOS, an operation expresses the realization of a requirement derived from the refinement of goals. Also the assessed concepts are not supported by all the languages. The concept of system requirement, as an independent and clearly defined concept, is only supported by KAOS and URML. Moreover, the concept of user requirements is represented by all the primary information that we can collect about the enterprise and its business. However there is no clearly defined construct to represent it.

As said before, when RE is oriented to software development and IS definition, it is highly related to enterprise modeling activities. All the modeling views are therefore necessary to gather the necessary knowledge about the enterprise. But not all the studied languages cover these modeling views. Thereby a single language is not sufficient to model all the views, a combination of languages is necessary to tackle the complexity of the information system to be modeled. Also, we aim at using the business view of SMEs' stakeholders as an entry point for the construction of the enterprise specific model and the system requirements, but all the studied languages require a specific knowledge in modeling notations. Adequate formalisms have therefore to be chosen to foster the autonomy of end users.

From our base of knowledge, there is no method that guarantees the autonomy of end users and that covers the modeling views to build a common understanding of the enterprise during the requirements elicitation and validation activities.

4 Proposition

It is here important to help SMEs' stakeholders build and share knowledge about their organization so that designers and developers would be aware of the environment for which they must provide solutions. So, we propose to guide software requirements engineering activities considering EM principals. In addition to the specification of the users' needs and system requirements, requirements engineering stakeholders will be provided with means to build the SME's enterprise model which will be used as a reference in the downstream software development activities.

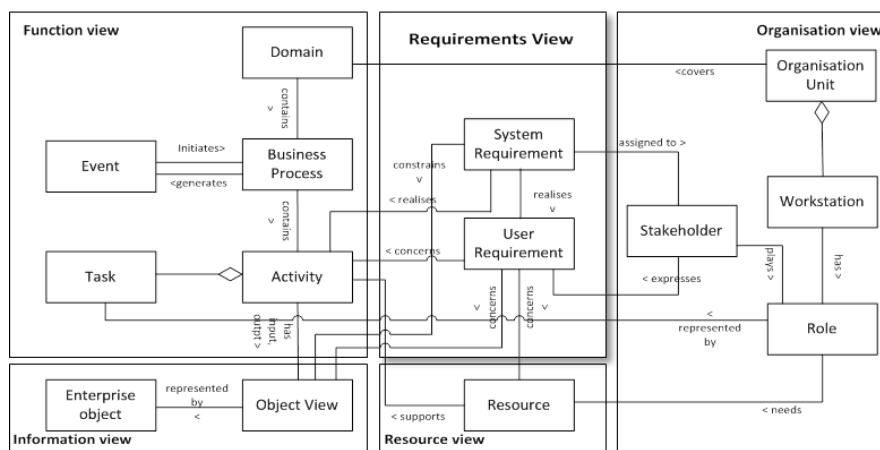


Fig. 1. Proposed constructs

We rely on the combination of the framework for enterprise modeling standard ISO19439 and the constructs for enterprise modeling standard ISO19440, which we extend with a requirements modeling view. Indeed, even if a user or system requirements uses concepts from the other views (informational objects and their states, e.g.: a vehicle can have more than one owner, activities and system functions e.g.: the car pound agent assigns the vehicle to a removal agent, etc.) requirements represent independent concepts necessary to gather clients' needs and justify design decisions. They are also important in all the project phases; a requirement document can for instance be used for project planning, cost estimation, scenario generation, etc. Even after decommission of an enterprise entity, it is important to know what motivated its creation in the first place. However, the standards do not offer any constructs to represent or distinguish between user requirements and system requirements. Such constructs allow modeling the way requirements relate to the other modeling views, assessing the matching level be-

tween user and system requirements and the traceability to design constructs. In the framework for enterprise modeling standard ISO19439 we take into account:

(i) all three levels of genericity, the generic level will be populated by a subset of the constructs for enterprise modeling standard ISO19440 enriched by requirements related concepts, the partial level will constitute typical generic patterns for a category of enterprises to be instantiated for a specific client. The particular level will represent the SME's enterprise particular model,

(ii) the enterprise model phases from the domain identification to the implementation description are considered. As we are concerned with sharing the knowledge collected in the requirement elicitation phase to the downstream conception and development activities, we gather the domain definition and concept definition phases into a user requirements definition phase,

(iii) to the four modeling views (function, information, resource and organization) that represent the aspects to be considered and the knowledge that has to be captured and stored during modeling activities. We propose to add a complementary requirements view (Fig 1.) to represent concepts addressed in the requirements definition phase and used in the downstream design and implementation phases. We distinguish user requirements from system requirements.

This standard framework is a support for consistency analysis and verification between the levels of genericity and the modeling views. The verification process allows assessing the correctness of the models and their compliance to meta-models. It is carried out through the definition of modeling rules, consistency rules and completeness criteria.

We are concerned with the definition of requirements that will be derived from the enterprise model and the user requirements definition. The modeling activities will be achieved by SMEs' stakeholders to whom we will provide a simple notation. We consider reasoning about daily practices and the way tasks are carried out to be an intuitive way for each business stakeholder to describe his role in the enterprise. Indeed they usually do not have a full, common image of business processes in which they are involved especially when these processes are cross-cutting different enterprise departments or business domains. In the same way, business stakeholders who may have this knowledge (head of the enterprise, head of departments, decision makers, etc.) do not know the detailed tasks performed by other stakeholders according to their roles. We propose a role based function oriented modeling process that comprises the four following paradigms:

Organization modeling and role definition: it is necessary to define the stakeholders' responsibilities. According to stakeholders' *workstation*— which are grouped into organizational units, single roles are defined where a *role* is the function that a *stakeholder* plays while intervening in business processes.

Function and behavior modeling: where the scope of the enterprise part to be modeled is defined and gathered into domains, a *domain* is a functional area representing a business of the enterprise, for each domain single roles are detailed into different *activities*, an activity being the locus of use and creation of information and resources, it can be defined by a number of elementary *tasks* and it has pre and post conditions represented by the state of the *objects* it uses. The activities will be gathered into *business process* models which are derived after the definition of business rules and control flow in the form of *user requirements*.

Information and resource modeling: *objects* and *resources* models are derived from the functional models, the activities description and the definition of business rules.

User requirements definition: will be performed all along the modeling process and *user requirements* will be collected to represent business rules and detailed descriptions. Other needs not always related to the ISO19440 modeling views can be collected, such as: non-functional requirements and expected behaviors of the SME' environment.

A tool will support the modeling process. It will be endowed with verification mechanisms in order to: (i) assess the correct utilization of the language by SMEs' stakeholders and the conformance of the produced models to their meta-models; (ii) detect contradictory behaviors among roles and processes definition. For instance situations where stakeholders intervening in the same business processes provide conflicting descriptions regarding the inputs, outputs or the order of the activities; and (iii) discern non-exhaustive descriptions where for instance the output of an activity (that does not represent the purpose of the business process) is not used by any other activity. Highlighting these errors, lacks and inconsistencies while producing enterprise models and user requirements will encourage SMEs' stakeholders to provide more information and organize their business processes.

Our SMEs computerization approach is based on an iterative requirements elicitation and validation process (Fig 2.) which is conducted upstream to software development activities.

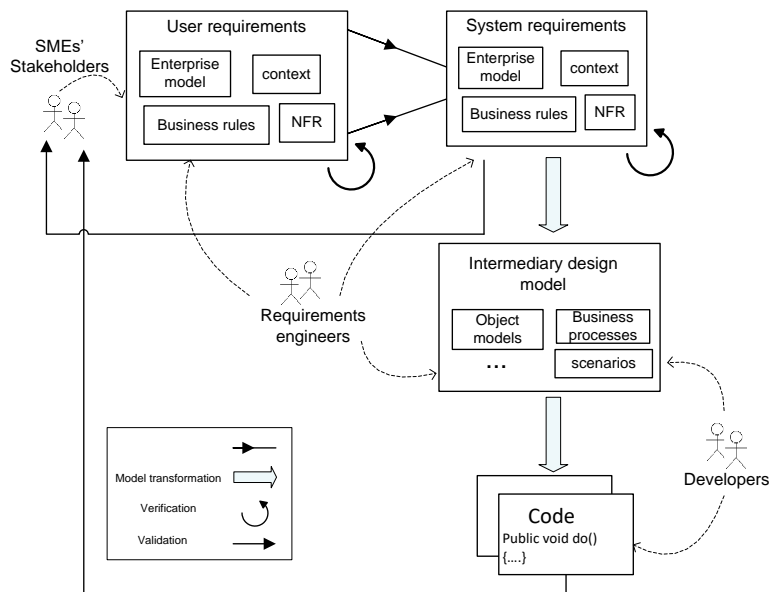


Fig. 2. Proposed framework

It starts by involving the SMEs' stakeholders (end users and business experts who represent typical roles in the enterprise) to express with a simple formalism their needs and their knowledge about the enterprise organization and functionali-

ties. Then, the user requirements will be refined by requirements engineers and will serve to formulate a well-written set of system requirements to be validated by the SME stakeholders. They will also serve to create a stable base of the enterprise model. Next, to speed up the process of understanding the business domain, we extract and represent the user's knowledge in some formal intermediary notation (standard UML diagrams, for example) through model generation. The generated models will then be completed and perfected by requirements engineers. Then, instead of only using requirements models and documents, the generated models serve as the basis for deriving code with model transformation techniques. This will accelerate the production of mock ups that will be validated and refined by the SMEs' stakeholders. The model generation and transformation process has the advantage to ensure conceptual and technical interoperability between the users' models and development tools.

5 Conclusion

Fostering the collaboration between the involved stakeholders during the software development's requirements elicitation and validation activities involves the construction, by the SMEs' stakeholders, of a common understanding about the structure and the behavior of the enterprise. We propose a requirements elicitation and validation process that is compliant with enterprise modeling reference frameworks and favorable to model transformations. The proposal is a work in progress. The notations, the modeling languages and the detailed concepts to be used have to be fixed. We will likely use a simple graphical formalism, coupled with natural language specifications. NLP techniques are under investigation to foster the autonomy of SMEs' stakeholders and provide a means for writing well-formed requirements with controlled vocabulary, rather than verifying requirements afterwards. To ensure the enhancement of the interoperability between the tools used in the computerization project, model transformation mechanisms from natural language to model based specification to code have to be settled.

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