Abstract

Recent Requirements Engineering research, recognises that successful system development relies upon the ability to model and understand the intentional structure of the organisational and business environment within which an IS is intended to operate. The importance of establishing and maintaining explicit links between information systems requirements and business goals is further emphasised by recent research in the areas of business re-engineering, systems evolution and change management.

This paper presents our approach for deriving and supporting decisions about system requirements based on the teleological paradigm. In this approach requirements for a new system are seen as the fulfilment or operationalisation of organisational and business goals. In contrast to conventional goal-oriented approaches in which requirements are derived by high level goals by a (mostly) top-down goal decomposition process, we perceive goal operationalisation as the iterative process of experimenting-in-action, using scenario generation techniques to refine enterprise goals to a level at which they have an operational definition.

1 Introduction

Conventional methods to information system development offer a prescriptive approach to Requirements Engineering. The traditional view of requirements definition is that this phase of systems development begins with an informal description of "what" the system is expected to do. However, recent Requirements Engineering research, based on industrial experiences, recognise that successful system development relies upon the ability to understand and represent not only what the system should do, but also "why" Yu and Mylopoulos [1], "Loucopoulos and Kavakli [2]", "Bubenko and Wangler [3]", "Potts [4]". Understanding the "why" dimension in systems development constitutes an important part of the knowledge about the Universe of Discourse. Such knowledge is necessary to ascertain and justify the presence of requirements components which are not necessarily comprehensive to clients and users.

In this approach the need to model and understand the organisational or business environment within which an IS is intended to operate is emphasised. Requirements for a new system are seen as the fulfilment or operationalisation of organisational and business goals, while requirements completeness is justified with respect to the "satisficing" of the stated goals "Potts [4]". The importance of establishing and maintaining explicit links between information systems and business goals is further highlighted by recent research in the areas of business re-engineering, systems evolution and change management "Duffy, MacNish [5]", "Yu [6]".

However, despite the recognised need for understanding the environment of IS, few methods have emerged that offer a systematic way to model enterprise goals. In most goal-oriented approaches requirements are derived by high level goals by a (mostly) top-down goal decomposition process "Dardenne, Lamsweerde [7]", "Anton, McCracken [8]". Top-down decomposition requires well-formed questions (i.e. the goals) and the provision of definite answers (i.e. the operationalisation alternatives). This is not always the case since the task of enterprise goal modelling often necessitates the development and resolution of concerns of multiple stakeholders and involves managing and communicating informal information. Therefore, instead of being predominantly top-down, the goal operationalisation process is highly iterative and open-ended. This perspective motivates our work discussed in this paper.

This paper presents our approach for deriving and
supporting decisions about system requirements based on the teleological paradigm. The issue of goal modelling is viewed in the wider context of enterprise analysis which includes the explicit modelling of: enterprise goals; user needs and requirements; their social roles and operations; and the synthesis of these perspectives towards a comprehensive description of the relevant parts of the enterprise. Goal operationalisation is conceived as the iterative process of experimenting-in-action, using scenario generation techniques to refine enterprise goals to a level at which they have an operational definition. Within this framework, scenario analysis methods are utilised to provide an orthogonal alignment between the generated scenarios and the task of requirements specification (functional and non-functional requirements). This approach addresses the issues of uncertainty, uniqueness and value in requirements specification, that cannot be addressed by technical rationalisation alone "Schön [9]".

The rest of the paper is organised as follows. Section 2 provides a survey of enterprise modelling issues and techniques adopted for representing enterprise knowledge, with special emphasis on teleology. In section 3 we discuss the reasons for the use of scenarios within the IS design process in general, and requirements specification in particular. In section 4 an approach is proposed for using the above types of knowledge that play a fundamental role both from the representation and reasoning perspective. We claim that teleological knowledge concerns the specific purposes for which the system has been designed, while scenario analysis is devoted to bridge the gap between such abstract purposes and the actual structure and behaviour of the system. Section 5 concludes with a comparison of our approach to other and by giving insights into future directions.

2 Enterprise modelling (EM)

2.1 Overview

Enterprise modelling is about describing in some formal way the enterprise setting and its mission, and provide a complete, comprehensive view of the current and desirable state of the enterprise. The main objectives of EM is: to improve and document the knowledge regarding the business enterprise; to provide a proper problem domain analysis; to encourage real user involvement, facilitating communication and co-operation among stakeholders; and to develop a basis for designing adequate IS to reach business goals.

Enterprise modelling is not targeted solely to Requirements Engineering. Its applicability spans over several IT related areas including: Computer Integrated Manufacturing (CIM) "Berio, Dileva [10]", "Kosanke and Vliestra [11]'', "Graefe [12]''; Enterprise Integration (EI) "Scheer and Hars [13]", "Goranson [14]", "Petrie [15]''; Business Process Re-engineering (BPR) "Curtis, Kellner [16]''; Computer Supported Co-operative Work (CSCW) "Aue and Breu [17]'', "Friedemann [18]'', "Benford, Mariani [19]'', "Sommerville and Rodden [20]''; and Information Systems Engineering "MacDonald [21]'', "Mercurio, Meyers [22]'', "Dobson [23]'', "Nellborn, Bubenko [24]'', Yu [25]''. In the above areas several more or less "formal" enterprise models have been proposed, in an attempt to address the nature of the organisation. The common link in all these models is that they try to embody social aspects to the enterprise such as the way the work is organised, how responsibilities are distributed, how human agents co-operate to fulfil their role etc. together with aspects from the objectives, service and operation domains.

Our enterprise model exploits the contribution of three interrelated viewpoints: teleological, organisational and operational. Each viewpoint encompasses a specific type of knowledge and representation. In particular, the teleological viewpoint uses a 'network' of goals to express the intents that stakeholders have about the potential system configuration. The organisational viewpoint models the make-up of social actors in terms of roles, individuals and organisational units. Finally, the operational viewpoint presents a behavioural aspect of the enterprise in terms of the processes that take place, the flow of information and data across business processes, where resources or organisations are located, where activities take place, etc.

The teleological approach emphasises the necessity to specify intentions and needs of the organisation, their interactions with the organisational processes and structure, and the deployment of appropriate technology. Focusing on the modelling of early business oriented views, the teleological approach advocates that an IS should be considered as the implementation of a set of operationalised goals which attempt to satisfy enterprise-specific objectives.

2.2 From enterprise goals to IS requirements

The informal user requirements are embodied in the teleological view of the enterprise model as the enterprise goals. These are elaborated into expressions of the system characteristics, i.e. the system functions and the constraints upon these functions.

This process includes the following stages:

1. goal modelling which involves the elicitation and refinement of enterprise goals, as well as identification of
antagonistic and synergistic relationships between goals, and

(2) operationalisation of refined goals to system requirements

2.2.1 Goal modelling. Goals express intention and capture the reason of the system to be built. According to their degree of specificity enterprise goals can be organised into goal hierarchies. Vague high level goals are refined into concrete, formal goals. This refinement is necessary because only simple primitive goals can be operationalised.

Goals can be grouped in different categories, depending on their context, owner, priority and so on. In general, each high level goal can be considered to belong to one of the following comprehensive categories: enterprise goals (reflecting general policy, strategy and tactics), problem-solving goals, and innovative goals.

Goals elicitation is likely to involve multiple participants who will hold multiple perspectives on a single domain. It becomes obvious that there is a need to express relationships between different goals, enact these relationships (e.g. check consistency and transfer information), and resolve conflicts when necessary. The derived interrelated goal network will inevitably give rise to a variety of implementational alternatives. These alternatives should be evaluated in some way to determine the degree to which a set of goals is supported by a particular implementation. The range of alternatives which are acceptable and realistically available to the enterprise is determined by: the specific combination of member competencies, commitments and influences which exist in the enterprise at any point in time; and the magnitude and patterns of the resources in hand or potentially available to the organisation, as described in the organisational and operational viewpoints of the enterprise model.

2.2.2 Goal operationalisation.

Operationalisation is the process of refining goals so that the resulting subgoals have an operational definition "Anton, McCracken [8]". The most common approach to goal operationalisation is that of goal reduction. Goal reduction is based on top-down decomposition. However, instead of being predominantly top-down, the goal operationalisation process is likely to be highly iterative and open-ended. In the following sections we describe a scenario-based approach, in which goal operationalisation is perceived as an iterative process, using scenario generation techniques to refine enterprise goals to a level at which they have an operational definition.

3 Decision scenarios to support system requirements

A decision is the articulation of knowledge (enterprise knowledge for our purposes), towards the realisation of a goal. Based on this, the teleological approach generates decision scenarios as a reasoning structure that fulfils a set of enterprise goals, based on knowledge accumulated from the relevant parts of the enterprise world.

3.1 Scenarios within requirements engineering

In order to address the origin of scenarios within requirements engineering, we view them as an agreement to two difficulties that requirements engineers are faced with: the incompleteness of the requirements engineering process, and the limited scope of the system requirements.

3.3.1 The incompleteness problem. For many years, the design process was viewed as a problem-solving activity, involving a number of quantifiable and non-quantifiable factors "Hillier, Musgrove [26]". Design work was directed at the methodological accumulation of information knowledge (by means of quantifiable components) and the replacement of intuition and rules of thumb with knowledge and methods of measurement. However, in this context the process of requirements elaboration could never be complete, mainly because the non-quantifiable variables, would always be present.

A different view advocated in "Cross [27]" states that design operates on the basis of prestructured viewpoints. These viewpoints, expressed as cognitive schemas, externalise how people, designers or users, interpret the world and prestructure their observations. The emphasis in this perception lies on the early employment of predicates and conjectures in the design process, to enable the structuring and understanding of the problem.

Based on the assumption that the main tasks of a requirements engineer are the analysis of the problem and the synthesis of potential alternative solutions, we conceptualise decision scenarios in terms of a knowledge repository that drives the requirements engineering process. In this context, we develop strategies that suggest a coherent framework that focuses on linking the established abstract functional and non-functional requirements with concrete descriptions of the system's dynamics.

3.3.2 The scope problem. According to "Alexander and Polymer [28]" "needs" are impossible to ascertain, therefore it is more appropriate to consider requirements as 'tendencies', the things people try to do
when given an opportunity. A tendency is perceived as an operational version of a need, hence it can be identified and tested by observing people's behaviours. A statement of a tendency is like a hypothesis, which can be tested, refined and made more accurate, or else evaluated to be wrong. Tendencies differ from traditional requirements mainly because of their ability to explicitly articulate the rationale behind them.

Scenarios, because of their adaptability to different social realities, are a promising way to capture the polymorphic nature of requirements, by interpreting observations in the organisational environment in terms of tendencies. Scenarios do not intend to be considered as the traditional activity logs of human actors, nor the keystroke-level models of engineering in general, rather they are meaningful and discussible by users. They are perceived at the level at which they can effectively reflect the enterprise environment, by describing what happens, how it happens and why it happens.

3.2 The impact of scenarios to the requirements specification process

The shift of focus to the behavioural context of 'needs' as tendencies, seems to have a number of impacts on the task of analysing and elaborating system requirements. Scenarios focusing on the target artefact, can define systematic strategies for meeting the system's dynamic requirements. In this sense, the design process, in general, becomes a 'cumulative scientific effort', as proposed by "Alexander and Polymer [28]", on the basis of defining the body of design knowledge in association with the body of enterprise knowledge.

The main benefits of defining systematic strategies to requirements elaboration and IS implementation can be summarised as:

- scenarios, utilised as a knowledge repository, envision the design process in an objectives rather than intuitive manner
- explicit modelling of means that function organisational objectives encourage and support systematic search of design solutions and possibilities
- early measurement of solutions to enterprise goals can achieve higher rates of success to implementation
- by giving an explicit understanding of how business work processes may occur through scenarios, this approach achieves an earlier agreement between stakeholders.

3.3 Scenarios: purpose and context

Scenarios have emerged as comprehensive mechanisms that capture the situations where design decisions need to be taken. They provide valuable information based on experimenting-in-action on practical cases. Scenario components aim at addressing concrete business situations and make 'intelligent' use of them, in order to drive and reason about design decisions. These decisions deeply analyse current and future enterprise and system objectives, and set the organisational environment where these objectives become operational.

Within the goal-directed approach of elaborating requirements specifications, we specialise to decision scenarios, to signify their existence as reasoning structures that track and inform about justified decision choices. A decision is a collective term that deals with: choices- the act of choosing or selecting among alternative options; positions- the act of establishing specific strategies that resolve problematic issues; operationalisation- the act of realising complex objectives to sequences of activities; and evaluation- the act of valuing the outcome against some criteria. Based on this definition of a decision, the purpose of scenarios is explicitly addressed at providing means that:

(a) trace alternative design possibilities,
(b) provide an agreement to alternative choices by selecting specific design strategies,
(c) realise these strategies with an operational definition, and
(d) evaluate the degree problematic design choices are resolved.

The context of scenarios is perceived as an assembling mechanism that gives a comprehensive and synthetic description of the relevant parts of the enterprise world. Scenarios are directed at describing how current of future enterprise goals may be operationalised, by informing about the ways business work processes can take place. They capture snapshots of organisational work activities, as well as the allocated resources necessary for them to occur. In other words, they conjecture the operational and organisational components, which gathered together exhibit design solutions to operationalising enterprise objectives.

3.4 Relating scenarios to requirements engineering activities

The teleological approach to requirements engineering encompasses a number of stage activities where scenarios can 'perform' specific roles. Scenarios, perceived as synthetic structures that trace, reason about, and operationalise design possibilities, function the following roles:

Introduction: Such scenarios capture decisions about
the new structure and relationships established in a web of enterprise and system goals, when a new goal is introduced. Design decisions in this case consider both refinement and lateral relationships between goals. This type of scenarios generate structural alternatives.

Planning: Such scenarios advocate decisions in respect to choosing a specific goal plan for future consideration. Deciding about which goal plan to elaborate in the enterprise and IS world, takes into account both single and lateral relationships among organisational goals, resulting to different planning alternatives.

Automation: Such scenarios reflect decisions relative to choosing which enterprise goals will be further elaborated in the system domain. In other words, such scenarios decide the goals to be automated in the target IS, producing automation alternatives.

Operationalisation: This type of scenarios decide about the operational and organisational components that best operationalise goals- either in the enterprise or the IS world. Such scenarios produce implementation alternatives, by featuring different operational definitions to the same goals.

Evaluation: Such scenarios decide whether current operational solutions to goals satisfy the implementation constraints suggested. By evaluating the degree to which current design solutions meet the constraints that confine the behaviour of a goal, the requirements engineer decides about the state existence of this goal. For that reason, these scenarios generate state alternatives for the goals in reference.

4 The scenario paradigm for a goal-directed requirements elaboration framework

We regard a scenario as a reasoning structure incorporating three dimensions, namely the functional, deliberative and spatial dimensions. The functional dimension reveals the actions described within the scenario, in terms of options, alternatives, conflicts, mechanisms and behaviours. The deliberative dimension reflects users' opportunities, preferences, intentions, goals and causal relations. Finally, the spatial dimension regards the scenario within the established boundaries of an envisioned system, that based on resources, has expected responses and effects when scenarios are activated.

The processes participating in the requirements elaboration framework are:

• Goal modelling, results to a high level set of business and ultimately IS goals, whose operationalisation will result to acceptable operational goal alternatives.
• Scenario generation, generates alternative scenarios that realise IS goals and yields to functional and non-functional requirements.
• Scenario visualisation, visualises the effects of the alternative scenarios, mainly by using techniques such as animating system specifications.
• Design rationalisation, traces, enacts and reasons about the processes of the design alternatives as captured by the set of scenarios.
• Goal refinement, results to a subset of the initial goal hierarchies, based on the process of observing how the executed scenarios meet the constraints of the attached design rationale.

5 Conclusions

In this paper we presented a teleological approach to Requirements Engineering. We focused on the relationship between enterprise goals and IS requirements, and the application of scenarios to the operationalisation of enterprise goals. Until now, scenarios have been used in goal-oriented approaches mainly for goal identification ("Potts [4]", "Dardenne, Lamsweerde [7]", "Rubin and Goldberg [29]", "Thebaut, Interrante [30]", "Holbrook [31]"), validation ("Potts, Takahashi [32]", "Carroll and Rosson [33]", "Anderson and Durney [34]" and prototyping purposes ("Rosson and Carroll [35]", "Hsia, Samuel [36]", "Hooper and Hsia [37]"). The novelty of our work is in the use of scenarios as the means of goal operationalisation.

The framework is still under refinement and a prototype implementation is underway. Our aim is to provide a support mechanism to facilitate the requirements elaboration process in an integrated tool environment, and to gain experience with the framework's strengths and weaknesses.

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