Where did the requirements come from? A retrospective case study

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Abstract. Understanding complex organisations in terms of their stakeholders' goals, intentions and resources, is a necessary condition for the design of present day socio-technical systems. Goal-oriented approaches in requirements engineering provide concepts and techniques to support this analysis. A variety of goal-oriented modelling methods are available, together with guidelines for their application, as well as real case studies success stories.
Our long term research objective is to derive useful suggestions for practitioners about which information sources are more promising for performing effective goal-oriented analysis and requirements elicitation of a complex domain, as well as about possible limits and pitfalls. As a first step towards this objective we perform a retrospective case study analysis of a project in the domain of ambient assisted-living residences for people affected by Alzheimer's.
In this paper we describe the design of this study, present an analysis of the collected data, and discuss them against the proposed research questions, towards investigating the effectiveness of information sources for goal modelling and requirements elicitation in complex domains.

Keywords: Requirements Engineering, Requirements Elicitation Techniques, Goal-Oriented Modelling

1 Introduction

Software systems for complex organisations are conceived as socio-technical systems (STSs), systems in which human and technological aspects are strongly interrelated. Eliciting the requirements for such systems builds upon a deep understanding of the involved human organisations in terms of the stakeholders' goals, intentions and resources, and of the role of technology towards enabling the achievement and maintenance of those goals.

Goal-oriented (GO) approaches in requirements engineering provide concepts and techniques to model social dependencies and to perform goal analysis, thus adopting a GO approach seems to be a natural choice. Experiences collected in complex real projects give evidence that different elicitation techniques need to be combined in order to better exploit the different sources of domain information and to model the various types of knowledge that characterise an STS domain.

The problem we face when starting a new project for developing an STS is how to identify useful domain knowledge sources and how to select the appropriate techniques for capturing knowledge and building an effective GO model for the intended STS. This relates to the requirements elicitation problem, which is largely addressed by the Requirements Engineering research community [9,4,8,6].

The long term objective of our research is to derive useful suggestions for practitioners about which information sources, among stakeholder interviews, domain documents, observations, etc., are more promising for performing an effective GO analysis of a complex domain, as well as about possible limits and pitfalls.

As a first step towards this objective we revisit our experience in applying GO approaches in real projects. Specifically, we investigate whether it is possible to derive empirical data about which information sources supported activities of modelling actors, goals, tasks, resources, and strategic dependencies and which knowledge elicitation strategy guided domain analysis and requirements collection, performing a retrospective analysis [10] of the *ACube* (Ambient Aware Assistance) project[1]. The *ACube* project application domain concerns an assisted-living residence called *Social Residence* for elderly people suffering

[1] The project was funded by the Autonomous Province of Trento in Italy (2008-2011). Detailed information about the *ACube* project can be found at http://acube.fbk.eu/.

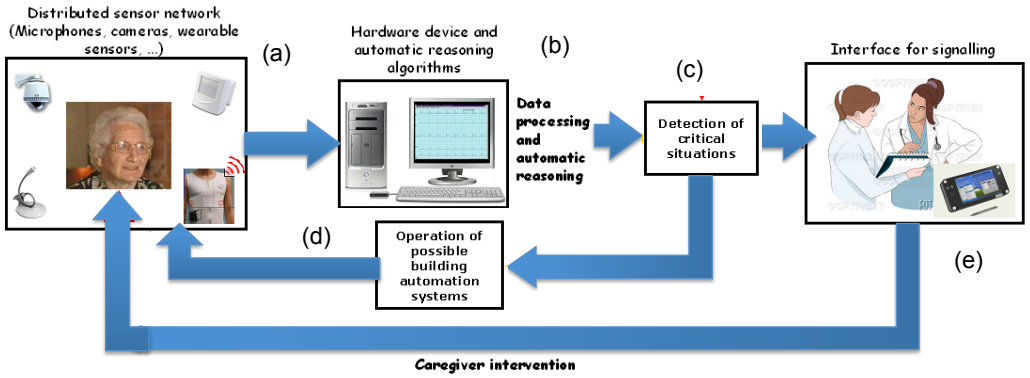

Fig. 1. A vision of the *ACube* system

Alzheimer's disease, who need continuous but unobtrusive monitoring of a variety of health-related issues. Worth mentioning is the heterogeneity of the stakeholders of social residences, including patients and their relatives, social workers, managers of the sanitary structure and nurses.

In our study, we perform a retrospective analysis of the project documentation, including the elicitation techniques, the trace links between requirements and goals, and the elicited set of requirements. This analysis is guided by three research questions. Moreover, two authors of this paper, who were acting as project analysts, were available for clarifying findings to the authors performing this project review.

The paper is organised as follows. In Section 2, we give an overview of the *ACube* project and of the requirements elicitation process that was adopted. In Section 3 we sketch the design of the proposed empirical analysis and the possible measures, to investigate on the use of the different information sources in GO modelling of a complex domain. First findings, extracted from the available documentation, are presented and discussed in Section 4. Related work is presented in Section 5, while Section 6 draws the conclusions and points out future work directions.

2 The *ACube* project

The *ACube* project aimed at developing an advanced, generic monitoring infrastructure for Assisted-Living, able to monitor in a uniform, adaptive, and high quality manner the patients of a social residence, the environment and its operators, and the ongoing activities, thus realising a highly developed smart environment as a support to medical and assistance staff.

The solution developed in the project exploits low energy consumption wireless networks of sensors and actuators. The resulting system, sketched in Figure 1, is based on: a set of sensors and actuators, which are distributed in the environment — e.g. microphones, cameras and alarms — or embedded in patients' clothes — e.g. biological sensors for ECG (see label (a) in Figure 1), and algorithms devoted to the higher level functions to assess monitored data and discover critical situations (see label (b) in Figure 1), which trigger configured actuators (d) or alarms calling for human operator intervention (e). All events are recorded for later debriefing by human operators. The communication infrastructure is designed for a high degree of configurability allowing to add new sensors to the system or to dynamically switch on and off sensors and actuators to save energy. This technology should allow an unobtrusive monitoring of the social residence guests.

2.1 Requirements Elicitation Artefacts and Process

In *ACube* an activity of paramount importance was the analysis of the requirements of the system, with the need of managing the trade-off between cost containment and improvement of quality of services in a specialised centre for people with severe motor or cognitive impairments, such as a social residence for elderly people. The project consortium had a multidisciplinary nature, involving software engineers, sociologists and analysts. Moreover, social residence professionals representing end users were directly engaged in design activities.

The joint use of both approaches User Centred Design [3] and Goal Oriented Requirements Engineering [5] allowed us to manage the multidisciplinary knowledge between stakeholders by balancing their

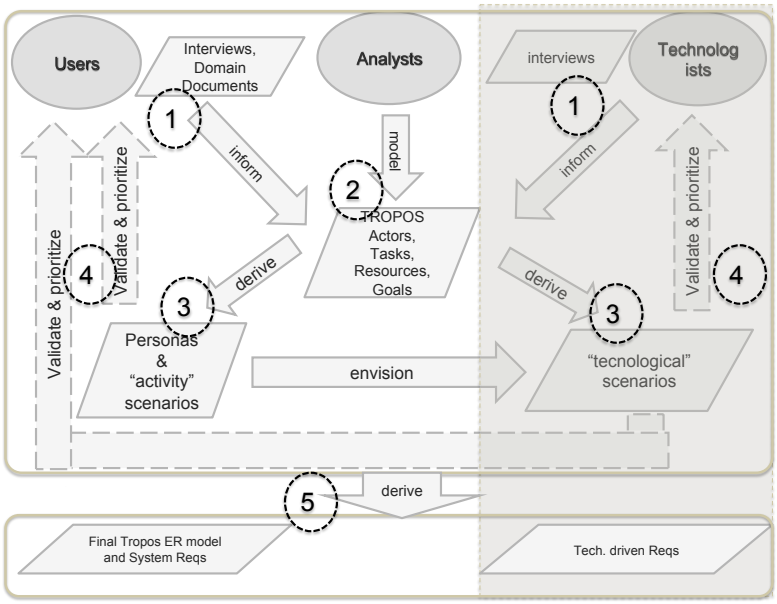

Fig. 2. A sketch of the *ACube* requirements elicitation and validation process.

needs and technical constraints, and in parallel by ensuring the validity, completeness and traceability of requirements. The requirements analysis phase of the project had a strict deadline of six month due to the schedule of the project, after which the technological team received the requirements in order to start the development.

The major sources of information in the project were the interviews with the domain stakeholders (in particular operators, doctors and managers), brainstorming sessions and domain document, such as the *Carta dei Servizi*, which describes the services the social residence is committed to give to the patients and to their families (such as reports on the condition of the patient) and the major activities to be performed to set up these services.

The major results of the elicitation and analysis phase were the definition of four different macro-services that the *ACube* system might provide: (i) "localisation and tracking of the patients and operators in the residence", (ii) "identification of the behaviour of the patients", (iii) "coordination of caregivers activity with a (semi) automatic report system" and (iv) "therapy management and administering".

Out of these scenarios and of the Tropos requirements diagrams a set of functional and non-functional requirements was generated. A first validation session was held with 27 researchers. A second validation session was organised with some of the stakeholders, including 3 managers and 8 operators of nursing homes previously involved in the early exploration phase. The goal of these sessions was the assessment of the validity, acceptability and feasibility of the requirements.

Most of the techniques and information sources used during the project, for eliciting, collecting and modelling data, belong to user centred design approach as well as goal oriented technique. In particular, we performed *an analysis of the existing documentation*, conducted *interviews* with domain stakeholders, led *brainstorming* to have feedback on the analysis of the domain and on the envisaged solutions, and modelled the domain via *goal-oriented requirements engineering* technique, by adopting the Tropos methodology [5].

The process followed in *ACube*, sketched in Figure 2, involves three roles — Users, Analysts, and Technologists — and can be divided into five main phases [7].

Analysis of the domain. Here a first activity of *analysis of the existing documentation* was performed, in particular of the domain document (see label "1" in Figure 2). Moreover, *unstructured and structured interviews* (also via questionnaires) with managers, doctors and caregivers were performed. In particular three representative sites (of different sizes) were selected for the research, resulting in 4 interviews with managers and 8 interviews with caregivers. The objective was to gather data directly from the context, to keep the richness of the data and avoid abstraction at the requirements level of the analysis, and to make analysts and stakeholders collaborate in understanding the domain.

Data interpretation and modelling. The data interpretation and modelling performed by the analysts, via goal oriented techniques, is the step in which data coming from the domain is shared across the team and

becomes knowledge (label "2" in Figure 2). In our process, data interpretation was concurrently carried out in a twofold way: (i) domain context analysis, and (ii) early requirements phase of Tropos to model retrieved information and to state hypotheses about the existence of entities (mainly goals and actors). Here the Tropos early requirements phase was executed in four iterations characterised by an increasing precision of the model and the reduction of open points that were clarified by using other techniques. The previous versions of the Tropos model were a source of information for the analysts to refine the subsequent versions.
Specification of user (activity) and technological scenarios. To obtain feedback from users and technologists, user scenarios were also used to envisage the technological scenarios (label "3").
Feedback via brainstorming sessions from both stakeholders of the domain and researchers. This activity allowed to confirm the validity of the retrieved models via feedback, from the domain stakeholders and researchers, and new iterations of contextual inquiry and questionnaires (label "4").
Retrieve system requirements and technical requirements. The model and list of requirements were released together with the final version of the Early and Late Requirements Tropos model (label "5" in Figure 2).

In the following we focus on the part of the process on the left in Figure 2, involving the interaction of users and analysts for the specification of system requirements.

3 Empirical Study Design

We perform a retrospective analysis of the *ACube* project by evaluating the available documentation along the following three questions:

- RQ1. Which information sources, among stakeholder interviews and domain documents, are relevant for the different types of knowledge captured in early-requirements goal models?
- RQ2. How did the different information sources contribute to model elements in different abstraction levels of a GO model?
- RQ3. In which way did goal models and information sources contribute to the elicitation of system requirements?

Measures. To investigate the first research question we use a quantitative analysis of a set of project's requirements artefacts, complemented by clarifications on specific aspects, which were asked directly to two project analysts. The quantitative analysis is carried out on the output of the *ACube* early requirements model delivered as tables with lists of entities, which were validated by domain stakeholders, and on the trace links from goal model elements to information sources, which were recorded during requirements analysis. We try to understand the major information sources for the elicitation of these elements, among the eight recorded interviews with domain stakeholders (2 managers, 1 nurse, 3 social workers, and 2 specialised collaborators), the available domain document, here the *Carta dei Servizi* of the social residence, and a preliminary version of an early requirements model. Moreover, the goal analysis itself, performed iteratively by organising goals and putting them in context, is an important source for new goal model elements. By analysing the trace links between goal model elements and the information sources, we count how many goals can be traced back to one or more among the above 10 information sources. We repeat this counting for actors, tasks, and resources. When no trace links were found, the original analysts are asked for clarifications.

The second research question is approached by trying to rebuild the early requirements goal model, with its hierarchies and dependencies, from the available goals and actors lists. Associating this goal model with the information sources and analysing the positions of the goals which emerged during the iterative construction of the goal model (source *Tropos ER model* in Table 1), detailed conclusions can be drawn on the goal-oriented elicitation process.

To analyse the third question we consider the early-requirements goal model, which has been validated by domain stakeholders, and the list of 78 requirements (of which 57 are functional) as the output of the *ACube* requirements elicitation process[2] illustrated in Figure 2. For each requirement we check the recorded links to goals in the validated early requirements model and transitively obtain the underlying information source. An analysis of the distribution of sources, actors, goals and plans is then made, to draw conclusions on the elicitation process. If there are no recorded links, we consider the following cases: i) check if the

[2] Notice that for this study we are not considering the technological requirements, which are also part of the output of *ACube*

Information source / Goal model elements	actors	activities	resources	goals	sum
Domain Document *Carta dei Servizi*	5	24	3	3	35
Interviews	18	15	18	10	61
Tropos Early Requirements Model	0	0	0	12	12
Total number of elements used in the Tropos model	20	27	19	24	90
Elements found using more than one source	3	12	2	1	18

Table 1. Contribution of information sources for modelling the Tropos elements

requirement refers to a task in the model, whose trace link was not recorded because an explicit means-end relationship between the task and a goal in the model was missing, or ii) enquire the analysts about possible mistakes.

4 Data and Analysis

We follow the analysis of the available *ACube* documents as described in the Section 3 and document the results.

The number of Tropos actors, tasks, resources and goals retrieved from the various information sources: from domain document (*Carta dei Servizi*), from interviews, and during the Tropos Early Requirements analysis, are reported in Table 1. The total number of entities, and the number of model entities that have more than one source, are also recorded. In general, in the analysed social residence domain, interviews produced the major part of elements in the early-requirements goal model.

Looking deeper at the results, we notice however that, for the activities to be performed, the domain document was the major source of information. This finding can be explained considering the fact that the activities represent services that are offered by the actors of the residence to the patients and to the external actors (such as families and control authorities), which are prescribed at the organisational and governmental level and that are mainly reported in the *Carta dei Servizi*. The remaining activities, extracted via interviews, are mainly internal and are necessary to provide the services described in the documents.

Regarding the actors, only few of them are extracted from the domain document, since a social residence has the freedom to establish by itself several roles in the organisation, and only few roles are fixed at governmental or institutional level. Looking at the single interviews, most actors are added in the first two (held with the coordinators of the structure), which seems reasonable, since these stakeholders know the organisational structure at best. In contrast, most interview partners mentioned resources needed for their work, thus they were added to the domain model quite uniform throughout the interviews.

Concerning the goals, they were retrieved from various sources, in particular from the interviews with the coordinators. However, also a specialised worker, the physiotherapist, gave rise to nearly 15% of the goals, while the social workers did not directly help to reveal new goals. Twelve goals were retrieved indirectly, during the goal analysis phase (i.e. in the Tropos Early Requirements Model). With the following analysis we are able to specify their source more precisely.

For answering to the second research question, we rebuilt the early requirements goal model, collecting the textual information available and the recorded goal dependencies, and annotating the artefacts with their original information source. Both the high-level goals and the leaf tasks (*activities*) are discovered already through interviews and domain document. Out of the 12 goals which emerged only during the analysis, 7 were internal goals added to create links between tasks and high-level goals, and the 5 remaining goals were introduced bottom-up, as motivation for an activity. The mix of top-down and bottom-up elicitation confirms the method proposed by Giorgini et al. [5], in contrast to previous guidelines.

From this analysis we can also state that the various layers of the goal model have been built exploiting the sources of information as reported in Figure 3: while the top and bottom layers of the model have their source mainly in domain document and interviews, the internal parts are often tacit knowledge [8], which seems either too “obvious” or too “abstract” to the stakeholders, and has thus often to be discovered by the analyst during goal modelling.

For answering to the third question we analyse the requirements document provided as output of the *ACube* project, which defines specific goals as the *motivation* for requirements. Joining information sources, requirements and the goal models obtained in the precedent analysis, we obtain an overview over the sources involved in the elicitation of requirements and the distribution of the various artefacts, which leads to various

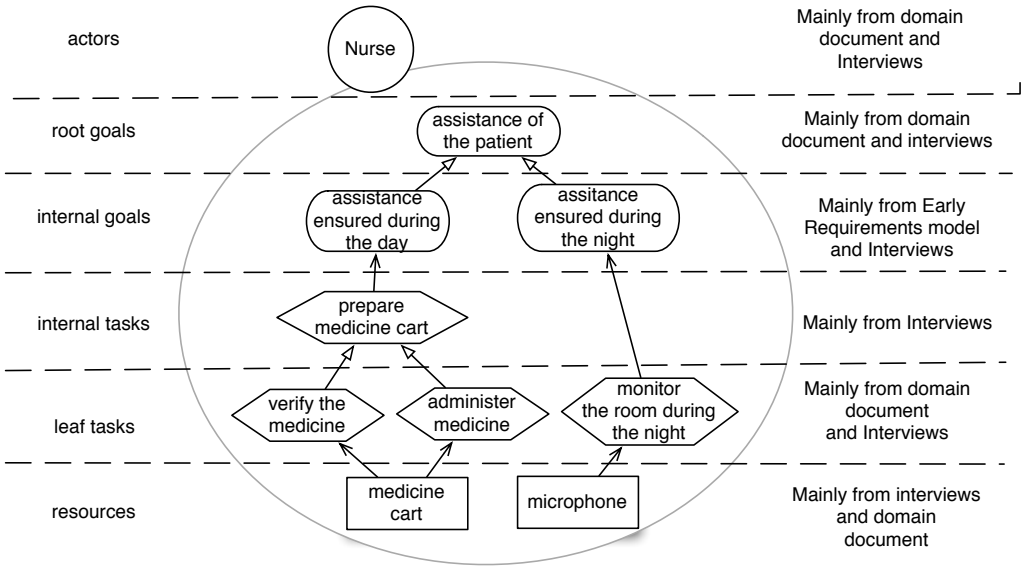

Fig. 3. Excerpt of a Tropos diagram representing a nursing home, with an explanation of the various goal model elements and the associated major sources of information in *ACube*.

Goal	Actor	Source	# of functional req.
G01 (provide nursing care)	A10 (social operator)	Interv. to coordinator	5
G07 (guarantee safety)	A10 (social operator)	Interv. to coordinator	13
G09 (optimise resources)	A03 (responsible)	Interv. to responsible	1
G10 (intervene promptly)	A10 (social operator)	Interv. to physiother.	11
G14 (improve the quality of service)	A03 (responsible)	Early Req. analysis	2
G15 (guarantee continuity of the service)	A03 (responsible)	Early Req. analysis	1
G16 (promote teamwork)	A03 (responsible)	Early Req. analysis	7
G17 (promote service personalisation)	A03 (responsible)	Early Req. analysis	6
G21 (manage emergency situations)	A07 (medical doctor)	Early Req. analysis	2
G22 (provide clinical surgery)	A07 (medical doctor)	Early Req. analysis	4
G23 (guarantee continuity of clinical surgery)	A15 (relatives)	*Carta dei Servizi*	2
G27 (manage clinical emergency)	A04 (guest)	Early Req. analysis	3
		Total	57

Table 2. Goals with the relative actors and sources, together with the number of requirements in which they are cited as motivation (only goals with a number of requirements ≥ 1 are shown) – translation from Italian.

observations. Table 2 shows that 40% of the requirements were motivated by only 2 of the 28 goals. Also, all the requirements are associated to goals of only two actors, the *responsible* and the *social operator*. This can be explained by the specific aim of the project, which was devoted to support the social operators in their daily work. We omitted the non-functional requirements, since, for most of them, no motivating goals were defined.

Looking at the transitive relationship between sources, goals and requirements reveals that most requirements (except the ones motivated by goals elicited during the analysis) arose from the interviews with the responsible and the physiotherapist.

However, these findings have to be critically examined: the goals attributed to some interview were often very general, such as “act promptly in critical situations”. In a second step, they can lead to various requirements which have few in common with the situation described in the original interview. This effect of goal modelling can be observed mainly due to the very condensed description of goals in a goal model and the missing (graphical) link to the information sources. Thus, these goals will be perceived by the analyst from a more abstract, high level viewpoint, and decomposed and operationalised accordingly. Moreover, the reliability of the available trace links was not verified and could thus be a serious threat to validity for the whole analysis.

Three out of the 78 identified requirements did not have any direct link to goals or information sources. A deeper analysis revealed that two of them apparently miss a link to the goals G10 and G01, while one requirement arises directly from the daily tasks performed by the caregivers.

5 Related Work

Research studies in requirements elicitation, and in particular on approaches based on GO modelling, are relevant for our work. First, the comprehensive survey review on empirical research in requirements elicitation by Dieste et al. [4], which derives some conclusions on relative usefulness of different elicitation techniques (e.g. structured interviews gather more information than unstructured interviews; unstructured interviews gather more information than sorting and ranking techniques; and interviewing is cited as the most popular requirements elicitation method). Second, some works define frameworks for the selection of requirements elicitation techniques, within a specific application domain, which propose supporting guidelines for practitioners, as for example [8] and [11]. In addition, [6] defines a general model for an iterative requirements elicitation process, in which the selection of a specific requirements elicitation technique is driven by problem, solution, domain characteristics and the actual requirements set to be consolidated.

In fact, for our long term objective we assume as a working hypothesis that the general model proposed by Hickey et al. [6] can be used in practice. This model uses domain characteristics and actual requirements for the selection process, so that we need to find out a way to characterise types of knowledge from them. This is motivating the retrospective analysis described in this paper, since it turns out that the elicitation process adopted in *ACube* can be seen as an instantiation of [6]'s unified model, in which the *ACube* early requirements goal model can represent the actual requirements.

For the specific elicitation techniques exploited in *ACube*, GO approaches applied in real projects in the health care domain such as [2] and, for STS, [1], are worth mentioning, confirming the usefulness of GO modelling to understand such complex domains and to elicit the requirements for STSs in these domains.

6 Discussion and Conclusion

In this paper we described a retrospective analysis of a project aiming at the development of an STS for a social residence for people suffering from Alzheimer's. Findings from a quantitative and qualitative analysis of the available documentation were reported. First, the information sources of the elements in Tropos early requirements model were presented. Among these information sources the domain document and interviews prevailed as the main sources for discovering elements for an early requirements model. Second, concerning the type of knowledge and the corresponding level of abstraction of model elements, knowledge about elements with lower abstraction, namely tasks, were captured mostly from domain documents, while actors and root level goals where mainly derived from domain stakeholder interviews. Moreover, an important number of goals was discovered only during goal modelling, connecting the different abstraction levels and finding the reasons for activities performed. This reveals that a mixed top-down and bottom-up elicitation strategy (as described by Giorgini et al. [5]) was adopted to perform modelling. The analysis shows again that a good documentation is important for keeping a clear understanding of the source of requirements and of the process that was followed by the analysts. Further investigations will be necessary to find missing trace links between the requirements artefacts (e.g., exploiting IR techniques). Moreover, the analysis will be extended to the whole requirements set, including technology-driven and non-functional requirements.

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