Goal Oriented Requirement Engineering: A Critical Study of Techniques

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Abstract

The term "Goal" is increasingly being used in Requirement Engineering. Goal-Oriented requirement engineering (GORE) provides an incremental approach for elicitation, analysis, elaboration & refinement, specification and modeling of requirements. Various Goal Oriented Requirement Engineering (GORE) methods exist for these requirement engineering processes like KAOS, GBRAM etc. GORE techniques are based on certain underlying concepts and principles. This paper presents and synthesizes the underlying concepts of GORE with respect to coverage of requirement engineering activities. The advantages of GORE claimed in the literature are presented. This paper evaluates GORE techniques on the basis of concepts, process and claimed advantages.

Keywords

Goal-oriented requirement engineering, elicitation, goal-oriented analysis, traceability, specification.

1. Introduction

Goals are intended outcomes to be achieved by the system under consideration [11]. Requirement engineering is concerned with requirement elicitation, analysis, specification, validation and requirement management [7] [15] [16] [12] [13] [14]. The concept of "Goals" is increasingly being used in requirement engineering [8]. GORE is concerned with the use of goals in various activities of requirement engineering as above. GORE research has its ancestry in AI research [4]. A variety of techniques have been proposed e.g. Deriving Tabular Event-Based Specifications from goal oriented requirement model (DTEBS) [2] GBRAM [5], AGORA [9], Visual Variability Analysis for goal models (VVA) [3], Goal-Oriented Idea Generation Method (GOIG) [6], Deriving Operational Software Specifications (DOSS) [10], Agent-Based Tactics for goal-oriented requirements elaboration (A-BT) [11], and goal-oriented requirement elicitation based on General System Thinking Heuristics (GSTH)) [4].

Goals are identified in an incremental manner. The questions *'why'*, *'how'* and *'how else'* leads the detection of goals [7], [4]. The *'why'* question helps to discover the objectives and rationale behind the goals which in fact identify the higher goals. This mechanism provides a solid rationale for each requirement; perhaps it is the natural way of doing the RE process [8], simply a requirement will not be considered if it does not contribute to any of the higher level goal in the hierarchy. The *'how'* question derive the identification of lower level goals unless the goals are fully operationalized. The 'how else' question helps to identify the alternates to satisfy higher level goals. This hierarchical arrangement provides the implicit advantages like traceability of requirement to higher level objectives, completeness of requirements and conflict identification [2].

This paper synthesis the underlying concepts and principles of GORE, and then evaluate GORE techniques on the basis of concepts. This evaluation can help researchers to move toward the unifying framework of GORE. An attempt has been made [16] to understand the role of goals with respect to RE activities, but the work is limited to only elicitation, specification and validation of RE activities and does not evaluate the techniques in relation to goal concepts.

The underlying principles of GORE based on General System Thinking (GST) and Cybernetics are proposed by [4] and then on the basis of this, concepts of achievement, maintenance, soft goals and their

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relationships are defined. They have also evaluated the concepts found in different GORE methods and finally extended the goal identification heuristics. However, the role and classification of goal concepts and techniques in relation to RE activities has not been taken into account, which is the major contribution in this paper. In addition, the criterion on which the GORE techniques are evaluated includes process, GORE claimed advantages, and tool support. This paper extends the GORE concept model presented in [4] to accommodate further concepts and techniques found in the literature.

There are certain advantages claimed from GORE literature, which are presented in this paper and an effort is made to evaluate some of them.

The concepts of GORE and their synthesis is presented in section 2. Brief overview of GORE techniques and their classification with respect to requirement engineering activities is given in section 3. Section 4 presents the claimed advantages which have been extracted from GORE literature. A comprehensive evaluation of GORE techniques based on concepts, claimed advantages and other evaluation criteria is made in section 5, and finally section 6 concludes the efforts made in this paper and guides for the future research.

2. GORE Concepts

GORE involves a number of related concepts rather than just the goal concept itself. In fact there is a family of related concepts present in the literature [1] [3] [4] [5] [9] [10] [11]. Goals are statements of intent and desired outcomes of the system under consideration. Agents are responsible for the fulfillment of goals. Agents are active components in system or its environment [10] [2]. Goals may be functional concerns or quality attributes required by the system [7]. The concepts of achievement goal, maintenance goal, soft goal, belief and constraint are defined in [4]. In this paper we accept these concepts with little addition in the definition of soft-goal concept based on [3], and add more significant concepts which are implicitly or explicitly present in the literature.

2.1. Goal Types

Goal types may be based on functional and non-functional requirements [1]. Three types of goals are identified and defined in [4], which are achievement, maintenance, and soft goals.

2.1.1. Achievement Goal. The achievement goal is fulfilled when its target condition is accomplished [5]. Concept of achievement goal is more precisely defined by [4]. It is related with regulative action that tries to keep an interpretation closer to a norm; or a learning action which can even change the system norms, interpretations and regulative actions.

2.1.2. Soft Goal. A soft goal is defined as a goal that has no clear-cut criteria for achievement [1]. The soft-goal model is related with the non-functional requirements [3].

2.1.3. Maintenance Goal. Maintenance goals have a condition that has to be remained constant [4]. Similar concept of maintenance goal is found in [5].

2.2. Belief

The concept of belief is associated with agent. It is the interpretation or viewpoint of an agent about its own state and the state of its environment [4].

2.3. Constraint

A constraint is defined by [4] as the limit on the achievement on a goal.

2.4. Goal Levels of Abstraction

Three levels of abstraction identified are described in Figure 1.

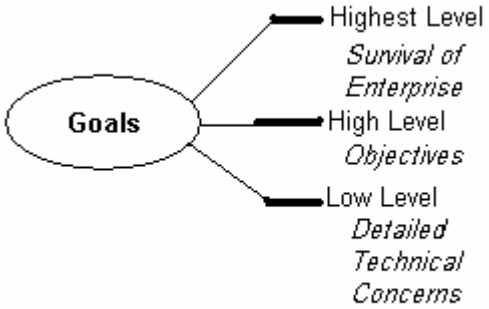

Figure 1: Goals Levels of Abstration

Goals are found at different levels of abstraction. High-level (strategic concerns), low-level (technical concerns) are found in [1], and the highest level goals related to the survival of the enterprise are found in [4].

2.5. Goal Taxonomies

Letier et all [10] have defined goal taxonomy based on operationalization patterns. Operationalization process maps goal specifications to software operations using formal derivation rules. The rules which define the operationalization patterns are formally proved correct once and for all.

2.6. Agents

Agents are active components of the system such as human, devices, and software [4], [11]. Goals are realized by agents who are responsible for the achievement of goals. Goal refinement decomposes a goal into sub-goals so that fewer agents are responsible for the goal, and the refinement ends when a goal is assigned to a single agent.

2.7. Requirement

Goal under responsibility of a single agent in the software-to-be becomes a requirement [11].

2.8. Assumption

Goal under responsibility of a single agent in the environment of the software-to-be becomes an assumption [1].

2.9. Goal Attributes

Goals can be characterized by their attributes, which can help us to make important decisions. The goal attributes identified in [1] are as under:-

- Name
- Specification
- Priority
- Utility
- Feasibility

2.10. Goal Links

Goal links provides the means to ensure different kind of traceabilities, Lamsweerde [1] has identified the following kinds of goal links:-

2.10.1. Inter-goal contribution links. The inter-goal contribution links capture the positive/negative contribution of one goal to other goals. Furthermore argumentation links can be used to attach related arguments to contribution link.

2.10.2. Operationalization links. Goals to operation links which have satisficing pre, post and trigger conditions used to formally specify goals, for the achievement of goals.

2.10.3. Coverage links. Coverage link Relate goals with the scenarios.

2.10.4. Responsibility links. A Responsibility link relates the goal and their responsible agent sub-models.

2.10.5. Wish links. These links help assigning agent a goal. For example, an agent should not be assigned a goal which is wishing for another goal that may cause conflict between the goals.

3. GORE Techniques

This section presents a survey of GORE techniques, their process and methodology. The GORE techniques evaluated in this paper are based on the criteria that the concept of goal-oriented should be given the central importance in the GORE techniques. The techniques based on other ideas but straddling into goals have not been selected as part of our evaluation.

Table 1 summarizes the GORE techniques with respect to the coverage of different requirement engineering activities, which are found in the literature [7] [15] [16] [12] [13] [14] and then synthesized. It has to be noted that requirement feasibility, risk analysis, and validation activities are also found in above mentioned literature but these are not included in the table 1 because no GORE technique which is included in this paper fall in these activities. These activities starts from the process of elicitation which involves domain analysis and identification of requirements and assumptions, then detailed analysis is done on elicited requirements which include classifying, modeling, and elaboration of requirements. After these activities conflicts have to be identified and resolved, conflicts may also be surfaced during previous activities.

Table 1: GORE Techniques w.r.t. RE Coverage

Elicitation		Analysis					Specification	Requirement Management			
Domain Analysis	Requirement and Assumptions identification	Classifying	Modeling	Elaboration	Conflict Identification and Resolution	Prioritization		Requirement Change/evolution Management	Traceability	Conflict Management	Measurement
GSTH	GSTH GOIG	GBRAM A-BT AGORA VVA	GBRAM A-BT AGORA VVA	GBRAM A-BT AGORA VVA	A-BT AGORA VVA	AGORA VVA	DOSS DTEBS	AGORA	AGORA GBRAM A-BT DTEBS DOSS VVA	AGORA	AGORA

Then the requirements needs to be evaluated for feasibility, and then prioritized which can help for planning and controlling the project. Risk analysis is also a vital activity of analysis. The specification activity is carried out after analysis, the requirements are formally specified in this activity. The validation activity confirms that have we collected the right requirements, and are the identified requirements correctly specified. Requirement management is an umbrella activity on all other activities, it consists sub activities like conflict management, requirement change management, measurement and traceability. The following presents a brief overview of GORE techniques.

GSTH [4] deals with requirement elicitation. It defines the highest level goals (a new level of abstraction) and proposes a set of heuristics based on General System Thinking (GST) and Cybernetics.

DOSS [10] deals with the Requirement Specification activity. It defines formal semantics for goals operationalization based on pre, post and trigger conditions; agents and their realization of goals and goal operations performed by agents; also defines taxonomy of goal patterns. Another technique DTEBS [2] uses the same models proposed by [10] for deriving tabular event-based specifications.

GBRAM [5] deals with Requirement Analysis activity. Set of heuristics (25 total) are proposed in GBRAM, 6 are related to Classification, 8 related to Refinement, 12 heuristics helps in Elaboration. In addition elaboration is supported by scenarios.

GOIG [6] is concerned with requirement elicitation. A process is defined for requirement elicitation based on idea-generation. Ideas are grouped into goals, and it mainly uses heuristics for idea-generation based elicitation.

Another requirement elaboration technique A-BT [11] mainly proposes tactics for resolving problems of un-realization of goals by agents. Goals are assigned to agents and agents realize goals. A goal is unrealized by an agent when agent cannot observer monitored variables or cannot control controlled variables. No formal process is as such defined.

AGORA [9] Strengthens to support selecting goals to decomposed, prioritizing, conflicts resolution, and quality estimation. It works by attaching attribute values (-10 to 10) to nodes and edges in the AND-OR goal graph. The values express how many degrees the sub-goal contributes to the achievement of its parent goal. Different score is given in each edge in OR and same value is assigned to all the edges in AND-decomposition. It uses preference matrix to find conflicts and gaps of understanding amongst different stakeholders (Customer, Developer, and Administrator).

VVA [3] deals with analysis and provide comprehensive reports for variability of requirements in order to achieve the satisfaction of stakeholders.

4. GORE Claimed Advantages

There are a number of claims of advantages made from GORE literature [1] [2] [10]. Following is the summary.

4.1. Requirement Completeness and Pertinence

Goals enable the sufficient completeness and pertinence of a requirements specification.

4.2. Rationale for Requirement

A requirement exists because it satisfies its higher goals. Any requirement which does not contribute to any goal will not be considered at all. For this reason

every requirement will have a rationale for it. Explaining requirements to stakeholders is another important issue. Goals provide the rationale for requirements.

4.3. Traceability

Goal graphs provide traceability links like from low level requirements to high level objectives and from organizational to business context.

4.4. Conflict Management

Contributions among goals (positive or negative) can be modeled and managed. In this way conflicts can be identified and resolved.

4.5. Managing Requirements Evolution

The higher-level a goal is the more stable it is likely to be. Goals are thus essential elements for managing requirements evolution [10].

5. Evaluation

This section presents a basic evaluation of GORE techniques, the evaluation criteria is based on the concepts defined in section 2, process / methodology, tool support, and traceability claims based on the goal-links concept. Note that the column of validation is not present in the tables because no goal oriented technique was found in the literature covering validation.

5.1. Concept-Centric Evaluation

Table 2 presents a concept-centric evaluation of techniques. It is worth to proceed forward for unifying framework of GORE by having same underlying concepts and principles. Note that there are certain concepts which are partially and/or implicitly present in different GORE techniques. The concept of agent is partially presented in [5] since it covers humans and software and does not talk about devices. Similarly the concept of belief is implicitly found in [9] as developers, customers, and administrators provide their viewpoint about the preference of a given goal to themselves and others.

Table 2: Evaluation based on Concepts

Concepts/Techniques		Elicitation		Analysis				Specification	Management
		GSTH	GOIG	VVA	GBRAM	A-BT	AGORA	DTEBS DOSS	AGORA
Goal Types	Achievement Goal	D	ND	ND	D	D	ND	D	ND
	Maintenance Goal	D	ND	ND	D	D	ND	D	ND
	Soft Goal	D	ND	D	ND	D	ND	D	ND
Goal Taxonomies		ND	ND	ND	ND	ND	ND	D	ND
Agent		ND	ND	ND	P I	D	ND	D	ND
Belief		D	ND	ND	ND	ND	I	ND	I
Assumption		ND	ND	ND	ND	D	ND	D	ND
Constraint		D	ND	ND	D	D	ND	D	ND
Goal Attributes	Name	D	D	D	D	D	D	D	D
	Specification	ND	ND	ND	ND	ND	ND	D	ND
	Priority	ND	ND	D	ND	ND	D	ND	D
	Utility	ND	ND	ND	ND	ND	D	ND	D
	Feasibility	ND	ND	ND	ND	ND	D	ND	D
Levels of Abstraction	Highest	D	ND	ND	ND	ND	ND	ND	ND
	High	I	I	D	D	D	I	D	I
	Low	I	I	I	D	D	I	D	I

ND: Not Present/Defined
D: Explicitly Present/Defined
P: Partially Present/Defined
I: Implicitly Present/Defined

5.2. Traceability evaluation

Traceability is evaluated in Table 3, on the basis of goal links concepts defined in section 2. It covers what kind of traceability is present or not in a given technique.

5.3. Tool Support

Table 4 summarizes the Tool Support available for techniques and also lists if the name of tool is available or defined.

5.4 Process Evaluation

The evaluation based on Process is also presented in Table 4. The techniques which have formally defined a process typically includes inputs, outputs, and step wise/methodological execution are marked 'Yes', and those techniques which do not have defined process but only proposed heuristics are marked 'No' in Table 4.

6. Conclusion

Goal oriented requirement engineering is an emergent research area. Various techniques and methods have been proposed, but a unifying framework can only be incorporated when there is an agreement on underlying concepts and principles used in GORE. This paper has presented the effort based on a concept-centric evaluation of techniques to move forward in this area. The contribution of this paper is to synthesize the underlying GORE concepts in order to develop a consensus on concepts which is necessary to move forward in this area. Secondly the role and classification of GORE techniques with respect to RE activities is emphasized, and finally evaluation based on concepts, claimed advantages, process, and tool support provides comprehensive means to judge and look forward in this area.

The future work can be done into the evaluation of claimed advantages made from GORE literature, and which are not evaluated in this paper, and to find how to make collaboration of different techniques.

Table 3: Traceability Evaluation

Traceability / Techniques		Analysis				Specification	Management
		VVA	GBRAM	A-BT	AGORA	DTEBS DOSS	AGORA
Goal Links	Inter-goal contribution links	D	ND	ND	D	ND	D
	Operationalization links	ND	ND	ND	ND	D	ND
	Responsibility links	ND	D	D	ND	D	ND
	Wish links	ND	ND	ND	ND	ND	ND

ND: Not Defined/Present
D: Defined/Present

Table 4: Tool Support and Process evaluation

	Elicitation		Analysis				Specification	Management
	GSTH	GOIG	VVA	GBRAM	A-BT	AGORA	DTEBS DOSS	AGORA
Tool Support	No	No	Yes	No	No	No	Yes, FAUST	No
Process	No	Yes	Yes	Yes	No	No	Yes	No

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