Measurement of Actor External Dependencies in GRL Models

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Abstract. Goal models represent interests, intentions, and strategies of different stakeholders in early requirements engineering. When capturing requirements of socio-technical systems, goal models evolve quickly to become large and complex. Hence, understanding and maintaining such goal models become more challenging. Software engineering metric-based approaches have shown good potential in measuring software designs. In this paper, we propose a structural metric to measure actor external dependencies in GRL (Goal-oriented Requirement Language) models. We illustrate our approach by applying our metric to a goal model describing undergraduate students' involvement in research activities.

1 Introduction

Goal models have been introduced as a means to ensure that stakeholders' interests and expectations are met in the early requirements engineering stages. As goal models gain in complexity (e.g., large systems involving many stakeholders and many dependencies), they become difficult to validate, maintain, and comprehend. These challenges led to the development of many goal-oriented metric-based approaches [1–4]. These approaches differ in their targeted notation, their purpose, their analysis type (e.g., quantitative, qualitative), and their scope (e.g., global, local). In order to support the assessment and selection of Commercial Off-The-Shelf (COTS) components, Franch and Maiden [1] have proposed and applied quantitative metrics to i* SD (Strategic Dependency) models. The proposed metrics are based on a classification of SD dependencies (e.g., duplicated and non-duplicated, hidden and non-hidden, etc.) and they are used to measure system properties such as diversity and vulnerability. Franch et al. [2] have introduced a generic framework with three structural metrics, aiming to evaluate system properties such as privacy and accuracy. The proposed framework supports both global and local metrics, and considers actor and dependency weights (i.e., importance values). Grau and Franch [3], have applied the approaches introduced in [1] and [2] to evaluate the effectiveness of alternative architectures based on metrics derived using the Goal-Question-Metric (GQM) approach. Sutcliffe and Minocha [4] have proposed a method to measure and analyze dependencies between systems and their users (described as an i* model) based on operational scenarios (e.g., using use case interaction diagrams).

To the best of our knowledge, none of the existing goal model approaches have conducted theoretical validation of their proposed metrics.

Many simple GRL metrics (e.g., number of goals, number of actors, etc.) are captured using the jUCMNav [5] tool, an Eclipse-based graphical tool that supports GRL (Goal-oriented Requirement Language) [6] modeling. In addition, jUCMNav [5] supports the computation of user-defined metrics (expressed in OCL). However, so far, no GRL-based quality metrics have been proposed.

The main motivation of this research is to provide a quantification of structural properties of GRL models. This paper aims to:

- Propose a quantitative metric to measure the Actor External Dependencies (AED) in GRL goal models (i.e., local metric at the actor level).
- Provide a basis for systematic assessment of goal models with respect to the interactions between the involved actors (i.e., global metric at the model level).
- Provide a theoretical evaluation of the proposed AED metric.

The remainder of this paper is organized as follows. Our proposed GRL actor external dependency metric is presented Sect. 2. In Sect. 3, we apply our proposed metric to a GRL model describing the involvement of students in research activities. A discussion of the benefits and threats to validity of our approach is provided in Sect. 4. Finally, conclusions and future work are presented in Sect. 5.

2 Measuring actor external dependencies

Dependencies enable reasoning about how actor definitions depend on each other to achieve their goals. Dependencies between stakeholders can be classified as explicit or implicit. Explicit dependencies are modeled as dependency links, while implicit dependencies are modeled using contributions $\longrightarrow$ and decompositions $\longrightarrow$ crossing actor boundaries. Explicit dependency links can be used in many types of configurations according to the required level of detail [6]. GRL actors can be used as source and/or destination of an explicit dependency link. Intentional elements inside actor definitions can be used as source and/or destination of a dependency link. It is worth noting that GRL is permissive in how intentional elements can be linked to each other. We further classify dependencies as internal (the source and the target of the dependency (explicit or implicit) are within the same actor), or external (the source and the target of the dependency (explicit or implicit) belong to different actors).

In what follows, we propose the Actor External Dependency metric (AED) to measure the GRL external dependencies at the actor level. The metric tends to measure the level of which the actor depends on other services provided by other actors. We use the term "element" to denote a GRL intentional element of type goal, softgoal, or task.

2.1 Metrics definitions

Dependencies between intentional elements are counted as follows:

- Explicit dependencies: Goal1 $\multimap$ Goal2, denotes "Goal1 depends on Goal2". Hence, the outgoing dependency link is counted as a dependency for Goal1.
- Implicit dependencies: (1) Goal1 $\longrightarrow$ Goal2, denotes "G1 is contributing to the achievement of G2", meaning that G2 depends on G1. Hence, the incoming contribution is counted as a dependency for Goal2, (2) Goal1 $\longrightarrow$ (Goal2, Goal3), expresses the fact that "Goal2 and/or/xor Goal3 contribute to the realization of Goal1". Therefore, the two decomposition links are counted as two dependencies for Goal1.

To measure the Actor External Dependency metric for actor a having k elements, we define the AED metric as follows:

$$AED(a) = \frac{\sum_{i=1}^{i=k} \frac{a(nAED_i)}{nSE - k}}{k}$$

where nAED (Number of Actor External Dependencies), denotes the number of external dependencies (incoming contribution and decomposition links, and outgoing explicit dependencies) for each element enclosed in actor "a", and nSE denotes the total number of intentional elements in the model.

In addition, we calculate the average model dependency for a GRL model with m actors as:

$$AMD = \frac{\sum_{n=1}^{n=m} AED(n)}{m}$$

Where AED(n) is the Actor External Dependency of actor "n".

2.2 AED theoretical validation

To validate the proposed metric theoretically, we use the properties proposed by Kitchenham et al. [7]. The authors [7] have proposed four properties to be satisfied in order for the metric to be theoretically valid. The theoretical validation of AED, based on these properties, is as follows:

Property 1 *Let A and B be two actors in a GRL model M. Assume that actors A and B have "i" and "j" elements, respectively. Also, assume that actors A and B have "k" and "m" total external dependencies, respectively, where $k \neq m$:*

$$AED(A) = \frac{\frac{k}{j}}{i} \;\; and \;\; AED(B) = \frac{\frac{m}{i}}{j} \;\; then \;\; AED(A) \neq AED(B)$$

Property 2 *Let A and B be two actors in a GRL model M. Assume that actors A and B have "i" and "j" elements, respectively, where i=j. Also, assume that actors A and B have "k" and "m" total external dependencies, respectively, where $k > m$, then: AED(A) > AED(B).*

Property 3 *Let A and B be two actors in a GRL model M. Assume that actors A and B have "i" and "j" elements, respectively, where i=j. Also, assume that actors A and B have "k" and "m" total external dependencies, respectively, where m = k+1. then:*

$$AED(B) = AED(A) + \frac{\frac{1}{i}}{j}$$

Property 4 *Let A and B be two actors in a GRL model M. Assume that actors A and B have "i" and "j" elements, respectively, where i=j. Also, assume that actors A and B have "k" and "m" total external dependencies, respectively, where m=k. then: AED(A)= AED(B).*

As AED satisfies these properties, then this metric is theoretically valid.

2.3 AED Interpretation

AED metric computes a normalized value for the actor external dependency. A lower AED value means the actor does not depend much on the services provided by other actors and hence, it is more independent. The higher the AED value, the more dependent the actor. Since AED metric measures the external dependency only, the internal connections within actors are not considered, and hence do not affect the metric value.

3 Case Study: Undergraduate Student Involvement in Research Activities

In this section, we apply the proposed AED metric to a GRL model (see Fig. 1) that describes undergraduate student involvement in research activities. The model involves two actors (Professor and Undergraduate Student) and describes one explicit dependency stating that "In order to ensure active involvement of students in research projects, professors depend on students to show their commitment to research activities". Research opportunities may take one of the following forms: (1) Perform programming duties, and (2) Perform experiments and data collection, (3) Perform engineering or scientific design tasks, and (4) Perform mechanical oand/or electrical assembly tasks. They are described as four tasks contributing positively (i.e., using the GRL *help* contribution type) to the softgoal "active involvement of undergraduate students in research projects". Student commitment to research activities is subject to either getting an academic credit for their performed tasks or have a financial support (through hourly wages) from professors.

The AED metric is calculated as follows:

$$AED(Professor) = \frac{\frac{5}{6} + \frac{0}{6} + \frac{0}{6}}{3} = 0.28$$

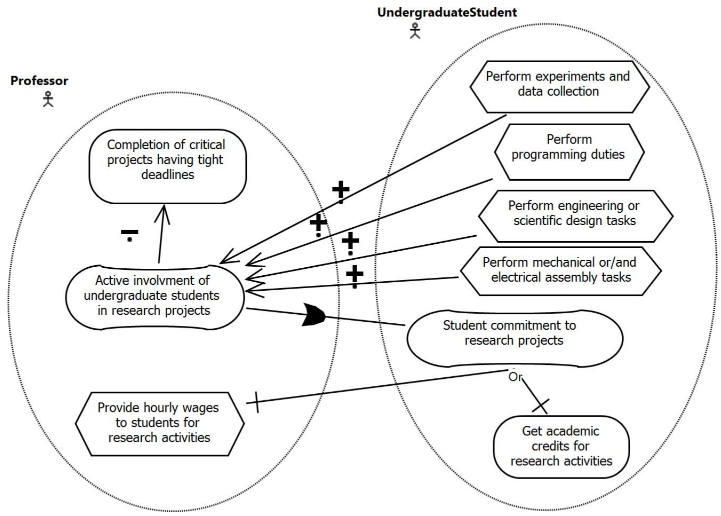

Fig. 1. GRL model describing undergraduate student involvement in research activities

$$AED(UndergraduateStudent) = \frac{\frac{0}{3}+\frac{0}{3}+\frac{0}{3}+\frac{0}{3}+\frac{0}{3}+\frac{1}{3}}{6} = 0.06$$

$$AMD = \frac{0.28 + 0.06}{2} = 0.17$$

The resulting AED metric shows a relatively high dependency of the professor actor compared to undergraduate student actor.

4 Discussion

In general system design, dependencies are clearly undesirable. However, in a socio-technical context dependencies may be desirable. For instance, it might be appropriate to offload a human actor by moving some of his responsibilities to a software actor (i.e., by implementing more automation), creating new external dependencies between the human and the software actors. Hence, specifying an adequate level of dependencies requires an expert judgment and the agreement of the intervening stakeholders. While a dependency metric helps the assessment of actor interactions within a GRL model, a theoretical framework is required to guide the model redesign.

A simplistic dependency metric would consider the number of outgoing connections regardless of how many elements an actor has, while the proposed AED metric considers the number of connections with respect to the elements an actor has, which tends to show the relative dependency.

Our metric and the illustrative example are subject to some limitations and threats to validity. These limitations and threats are related to the extent to which our results can be generalized. A possible threat is that we have considered all external relations to have the same weight. However, defining a dependency weight will always be subjective and hence we have decided to ignore the weight factor. Another possible threat is that we only proposed the Actor External Dependency. Although, this metric by itself may not provide a complete picture to understand the system complexity or dependency, it seems to be a good indicator.

5 Conclusions and future work

The quantitative Actor External Dependency (AED) metric described in this paper provides a basis for systematic investigation of socio-technical system dependencies expressed in the GRL language. We have validated theoretically our proposed metric and have applied it to a GRL example to demonstrate its applicability. As future work, we plan to propose a metric to measure the actor internal dependencies (i.e., between intentional elements within an actor) and another metric to measure actor stability.

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