Uncertainty in Goal and Law Modeling and Analysis

Silvia Ingolfo, Jennifer Horkoff, John Mylopoulos

University of Trento, Italy

Abstract. Goal models are widely recognized as an effective means for capturing requirements for socio-technical systems. Recently, models of law have been investigated and analyzed in conjunction with goal models, in order to evaluate the legal compliance of software system requirements. As goal models capture social, often ill-defined concepts, and as law models capture ambiguous legal settings, both models are characterized by the presence of uncertainty. Consequently, both goal and law models consider uncertainty as part of their analysis, allowing for unknown or inconclusive analysis labels. However, it is also possible to consider uncertainty in the content of such models. Recent work has applied an existing formal method for capturing uncertainty in goal models. In this paper we make a distinction between uncertainty in analysis and uncertainty in content, reporting on the influence of such uncertainty in models of law and requirements.

1 Introduction and Objectives

The usefulness of goal models (such as i* [1]) in capturing socio-technical requirements is widely recognized in Requirement Engineering. The impact of the law in both functional and non-functional requirements has gained a lot of attention in recent years. Software that is not designed in compliance with applicable laws can cause great economic damage to organizations. To limit such outcomes, it has become imperative to establish of a software system as early as the requirement phase. So on one side we have goal models for representing requirements, and on the other we want to represent and model law. The Nòmos 2 framework [2], inspired by RE ideas, models laws in terms of *norms* and *situations*. The link between these models provides a previously missing step toward the evaluation of regulatory compliance of a requirements model [3].

As goal models capture early, social requirements, uncertainty is an unavoidable factor that has not been widely investigated. Uncertainty is also present in laws, arising from the intricate structure of law, as well as ambiguities and exceptions. Although law models (e.g., Nòmos 2 [4]) can take legal variation into account, they cannot easily express uncertainty over these variations, or exploit uncertainty information as part of analysis.

In this paper we cover two categories of uncertainty: (1) uncertainty in analysis results and (2) uncertainty captured in the model structure. The first type of analysis has been explicitly considered for both goal and law models. Recent work has considered (2), explicitly capturing uncertainty over the structure of goal models [5]. We consider the application of these ideas to law models, and outline future work which may combine (1) and (2) for goals and/or laws.

Objectives: In this paper we discuss the explicit consideration of uncertainty in both goal and law modeling and analysis, exploiting the synergies of existing work, and outlining new avenues of uncertainty-related investigation.

2 Background: Nòmos 2

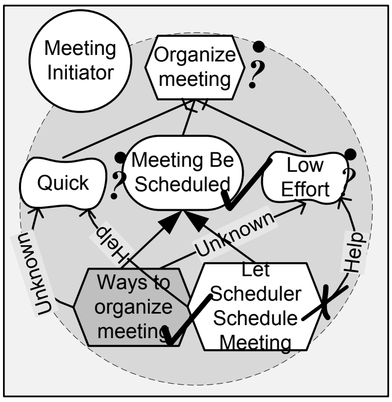
Nòmos 2 [4,6] is a modeling framework for representing law. The concept of Norm is defined as a 5-tuple $(type, holder, counterpart, antecedent, consequent)$. $Type$ is the type of the norm (e.g., duty or right). *Holder* is the role that has to satisfy the norm, while the *counterpart* is the role whose interests are helped if the norm is satisfied. *Antecedent* and *consequent* are modeled in terms of situations and they represent the conditions to satisfy to make the norm applicable (antecedent) and the conditions to satisfy in order to comply with the norm (consequent). A situation is defined as a partial state of the world – or state-of-affairs – represented as a proposition which can be true, false, or have an unknown truth value.

The idea behind Nòmos 2 is that a set of situations make a norm applicable and similarly situations can satisfy the norm. To capture this applicability and satisfiability, we model the relations between situations and norms as label propagation mechanism. The two relations for satisfiability ($satisfy/break$ propagate positive/negative satisfiability) and two relations for applicability (*activate*/*block* propagate positive/negative applicability) link situations to norms. In Nòmos 2 situations are propositions that can be known to have Satisfiability True (ST), False (SF), or Unknown (SU). Similar label are propagated by the relations for Applicability (True AT, False AF, Unknown AU). Depending on the satisfiability of the input situations, the target norm receives true/false/unknown values for satisfiability and applicability. The combination of this two values defines the compliance value for a norm (compliant, not-compliant, tolerated, or inconclusive). Composite relations (*derogate*, *endorse*, *imply*) capture the relations between norms [4]. In figure 1b we show an example of a Nòmos 2 model representing a simplified norm about VAT-tax.[1]

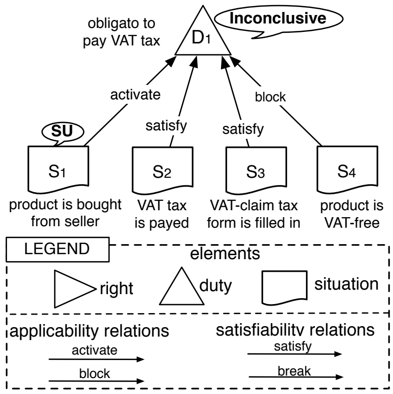
When a product is bought (sat(s_1)=ST), the relation $s_1 \xrightarrow{\text{activate}} D_1$ propagates positive applicability to the norm. When the situation s_2 is also satisfied, then the relation $s_2 \xrightarrow{\text{satisfy}} D_1$ propagates positive satisfiability, and we say that the duty is complied with (it is applicable and satisfied). Propagation for s_3 is similar. However when s_4 holds (the product is VAT-free), then the relation $s_4 \xrightarrow{\text{block}} D_1$ propagates negative applicability (label 'AF') and the duty is not applicable.

[1] The graphical notation used to express the label is only used for illustrative purpose.

Proceedings of the 6th International i* Workshop (iStar 2013), CEUR Vol-978



(a) Example i* Analysis over a Subset of a Meeting Scheduler Example



(b) Example of a Nòmos 2 model for the duty to pay VAT-tax on product.

Fig. 1: Analysis Examples Showing Uncertain Analysis Results

3 Scientific Contributions

We make the distinction between uncertainty in analysis results and uncertainty over the structure of the model. In this paper, the former refers to uncertainty about the satisfaction or applicability of a particular model element, while the latter refers to uncertainty about the presence, uniqueness, or number of model elements and links. We illustrate this distinction in the following.

3.1 Uncertain Analysis Results

Goal Models. Goal models have long provided a "lightweight" consideration of uncertain analysis results using the *unknown* contribution link and *unknown* analysis value (?), with the former intended to represent a contribution with an unknown type (e.g., help, break), and the latter meant to represent the presence of evidence with unknown polarity (satisfied/denied) and strength (full/partial) [7,8]. For example, in Figure 1a, part of a simple meeting scheduler example, we propagate initial satisfied and denied labels through two unknown contribution links, producing unknown analysis labels for Quick, Low Effort, and ultimately for Organize meeting.

Nòmos 2 Models. On the legal side, a Nòmos 2 model allows us to express and reason about the uncertainty related to the situations holding, as well as the consequences this uncertainty has on the compliance of the model. The analysis of these models can therefore explore how the uncertainty in the situations holding (e.g., domain assumptions or hypothetical scenario) affect the compliance with applicable laws. For example in the scenario where it is unknown whether a product is bought (sat(s_1)=SU), then the applicability of the norm is unknown because the relation $s_1 \xrightarrow{\text{activate}} D_1$ propagates unknown applicability. In

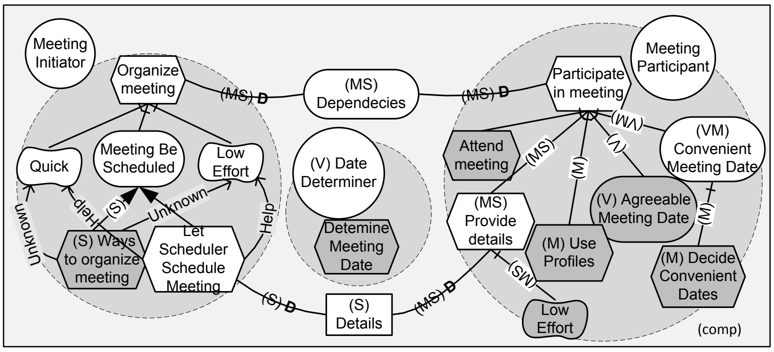


Fig. 2: Uncertainty Annotations in an i* Model (from [5])

Nòmos 2 the norm is evaluated to `inconclusive`: when it is not known whether the norm applies or not, it is not possible to infer any conclusions about it.

Discussion. Both goal and law models allow for unknown analysis values as initial values/assumptions, starting analysis. Such uncertainty is propagated using existing reasoning procedures, as described. Unlike Nòmos 2 models, goal models contain a simple form of uncertainty in the type of contribution relation. We explore this type of uncertainty — uncertainty over model structure — in the next section.

3.2 Model Uncertainties

Goal Models. Previous consideration of uncertainty in the structure or contents of goal models was limited only to uncertainty in contribution links (unknown). Although useful, uncertainty may occur in any relationship or element. Recent work has used the *MAVO* formal uncertainty framework [9] in order to capture uncertainty in a more general and expressive form. In this approach, we limit our focus to possibilistic uncertainty, as opposed to probabilistic uncertainty.

MAVO is a language-independent approach for formally expressing uncertainty in models. It allows users to express uncertainty using a set of annotations over elements and relationships in their model. As these annotations can be applied to any type of model (any metamodel), the approach is language independent. Specifically, the approach allows for annotations M, V, and S over model elements and links, and COMP (complete) or INC (incomplete) for the entire model. We illustrate application of this framework to i* in Figure 2 adapted from [5].

The M (May) annotation allows us to express uncertainty about the presence of an element or link in a model. In our model, we are uncertain, for example, about whether we really need to Use Profiles as part of Participate in Meeting. The V (variable) annotation allows use to express uncertainty about element distinctness. We are uncertain if Agreeable Meeting Date and Convenient Meeting Dates are distinct goals, or could be merged. The S (set) annotation represents uncertainty about the number of elements, elements which may be sets. We know we must provide Details, but are not sure if there is one detail, or many, or what those details are. We mark the entire model as COMP, meaning that there should be no more new elements or relations.

MAVO captures uncertainty formally by expressing metamodels and constraints in First Order Logic, removing constraints which ensure the presence, distinctness or number of each element in the formalism. This allows use of existing solvers to find "solutions", corresponding to concrete, uncertainty-reduced models. More detail can be found in [9,5].

Nòmos 2 Models. As Nòmos 2 models are also characterized by uncertainty, such a general uncertainty framework could be applicable. The possibility to express uncertainty in the structure of a Nòmos 2 model, could be useful when sources are uncertain. For example we could annotate the fact that a situation "product bought at the airport" May block (make not applicable) the duty to pay the VAT-tax. The uncertainty related to this annotation arises because not all airport products are tax-free: the ones bought at the duty-free are, but products at regular shops usually include VAT. Similarly we could annotate that we are uncertain whether it is enough to fill in the VAT-claim form or maybe there is something else to provide in order to be really compliant. For example, when submitting these VAT-claim forms at the custom office, some identification documents are needed for the passenger. However, it could be that the proof a valid return ticket is also needed to really comply. We can model this using MAVO by adding additional S and M annotated situations (e.g., (M) valid return ticket is provided, (MS) passenger identification documents provided) which can satisfy the norm. Further investigation and examples are needed to evaluate the combination of Nòmos 2 and *MAVO*.

Discussion. In this section we have explored uncertainty over the structure of the model, while previous considerations of uncertainty assumed that the model was certain but considered uncertainty in analysis values. In some cases, the border between uncertainty in model structure and analysis results is difficult to define. We provide a preliminary sketch of these dimensions in Figure 3. Existing approaches for goal models consider only a small amount of model uncertainty (unknown links) and uncertainty in analysis using the unknown label (point (1) in Figure 3). Nòmos 2 considers uncertainty in satisfaction and applicability as part of analysis, but does not consider uncertainty over the model (point (2)).

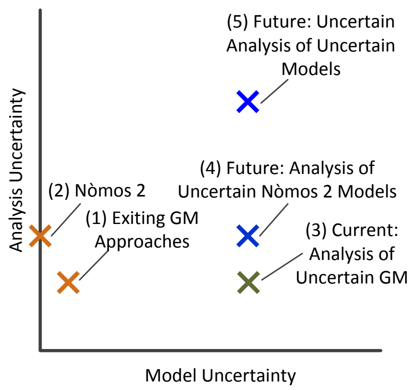


Fig. 3: Model vs. Analysis Uncertainty - Existing and Proposed Approaches.

We can envision investigation using other combinations of these dimensions. We are currently investigating ways to apply i* analysis over *MAVO*-annotated i* models (point (3)). This work would allow us to explore analysis results given possible uncertainty reductions, in order to explore alternative requirements by producing sets of possible labels even before uncertainties are resolved. Similar approaches could integrate the semantics of Nòmos 2 models with *MAVO* annotations, considering uncertainty in the evaluation of compliance (point (4)).

By analyzing uncertain goal models, we increase our consideration of model uncertainty (beyond unknown links), but do not consider any further uncertainty in analysis results (beyond the use of unknown labels). Future work could support analysis which allows for the possibility of more uncertainty over possibly uncertain models (point (5)). For example, if we explicitly consider the effects of an open world assumption (Incomp) during model analysis, the possibility of additional elements and links may cause further types of uncertainty in our analysis results (e.g., an element may be satisfied). Our definition of model vs. analysis uncertainty may evolve as we consider such possibilities.

4 Conclusions and Future Work

In this paper we make the distinction between uncertainty over the contents of the model (model uncertainty) and uncertain analysis results (analysis uncertainty). We have summarized uncertainty as considered in the analysis of i* and Nòmos 2 models. We have summarized existing work on model uncertainty for goal models, and provided examples of how such work can be applied to Nòmos 2 models. We outline possible future work considering other combinations of uncertainty in modeling or analysis. In the future, we may need further distinctions to characterize uncertainty, e.g. design-time uncertainty over model contents vs. run-time uncertainty over unpredictable aspects of the environment.

References

1. E. Yu, “Towards modelling and reasoning support for early-phase requirements engineering,” in *Proceedings of 3rd IEEE International Symposium on Requirements Engineering*, vol. 97, pp. 226–235, IEEE, 1997.
2. A. Siena, S. Ingolfo, A. Susi, I. Jureta, A. Perini, and J. Mylopoulos, “Requirements, intentions, goals and applicable norms,” in *RIGIM - ER Workshops*, p. 195, 2012.
3. S. Ingolfo, A. Siena, and J. Mylopoulos, “Establishing regulatory compliance for software requirements,” in *Conceptual Modeling - ER 2011*, vol. 6998 of *Lecture Notes in Computer Science*, pp. 47–61, 2011.
4. A. Siena, I. Jureta, S. Ingolfo, A. Susi, A. Perini, and J. Mylopoulos, “Capturing variability of law with Nòmos 2,” in *Conceptual Modeling - ER 2012*, vol. 7532 of *Lecture Notes in Computer Science*, pp. 383–396, 2012.
5. R. Salay, M. Chechik, and J. Horkoff, “Managing Requirements Uncertainty with Partial Models,” in *Proc. of RE'12*, 2012.
6. S. Ingolfo, A. Siena, I. Jureta, A. Susi, A. Perini, and J. Mylopoulos, “Choosing compliance solutions through stakeholder preferences,” in *REFSQ 2013*, vol. 7830 of *Lecture Notes in Computer Science*, pp. 206–220, 2013.
7. L. Chung, B. Nixon, E. Yu, and J. Mylopoulos, *Non-Functional Requirements in Software Engineering*. Kluwer Academic Publishers, 2000.
8. J. Horkoff and E. Yu, “Interactive Analysis of Agent-Goal Models in Enterprise Modeling,” *Int. J. Inf. Syst. Model. Des. (IJISMD)*, vol. 1, no. 4, pp. 1–23, 2010.
9. R. Salay, M. Famelis, and M. Chechik, “Language Independent Refinement Using Partial Modeling,” in *Proc. of FASE'12*, vol. 7212 of *LNCS*, pp. 224–239, 2012.