A Framework for Distributed Collaborative Conceptual Model Development

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Abstract

One of the major concerns in the processes which involve human analysts is the existence of uncertainty/inconsistency. In this paper, we propose a model based on belief theory that attempts to capture the degree of analysts' uncertainty towards their expressed specifications and employs these information to create an integrated unique model.

Categories and Subject Descriptors D.2.1 [*Requirements/ Specifications*]: Methodologies

General Terms Design, Reliability, Management

Keywords Collaborative Modeling, Viewpoint Integration, Conceptual Modeling

1. Introduction

Software engineers have been interested in using information from multiple sources for creating concrete, consistent and complete compilations of software requirements. In this process, sources of information are mainly known as viewpoints. Nuseibeh defines viewpoints as 'loosely coupled, locally managed distributed objects which encapsulate partial knowledge about a system and its domain, specified in a particular, suitable representation scheme, and partial knowledge of the process of development' [2]. Although not all models of viewpoint-based requirement engineering conform to this definition, most of them roughly agree on this basis. There are various issues that need to be addressed before viewpoint-based models can be correctly employed. Firstly, humans usually make conception errors due to risk aversion, short-term memory or even framing and perceptual problems [1]. This implies that not all asserted information from the sources are correct or equally reliable. Furthermore, epistemic uncertainty (also known as partial ignorance) is an indispensable element of human judgments that makes them even more susceptible to inaccuracy and imprecision [3]. There are three major theoretical frameworks through which uncertainty can be handled and manipulated, namely imprecise probabilities, possibility theory, and Dempster-Shafer theory of evidence [3]. Here, we intend to formalize the process of viewpoint -based conceptual model development and integration through the notion of belief from within the framework of Subjective logic [1].

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2. Framework Overview

The model that we propose in this paper is founded on the degree of experts' uncertainty towards their expressed specifications. To capture the degree of uncertainty, we employ a three dimensional belief structure based on Subjective logic. This belief structure allows opinions to be expressed with varying degrees of belief, disbelief, and uncertainty. Furthermore, we define and employ an underlying language construct so that higher level conceptual modeling formalisms (e.g. UML, ERD, OWL, and etc.) can be translated through it onto the belief structures. The exploitation of these two basic elements (the three dimensional belief model and the underlying modeling construct) would allow us to reason about different specifications that are coming from multiple sources.

One of the important phases of the collaborative conceptual model development process is viewpoint merging. This is performed on the basis of belief merging operators such as Dempster's rule of combination. The only restriction that we apply on the expressed specifications is the use of a common application vocabulary. The repository is incrementally developed and shared as the viewpoints define and express their models. The common set of vocabulary is required so that specification overlaps are detected. We define three metrics for analyzing the effectiveness of the merging process and the quality of the obtained model. These metrics can assist the analysts in the process of decision making and planning. The proposed model also develops and guides a formal negotiation process between the viewpoints so that a stable consensus is faster developed by recommending proper portions of belief that need to be assigned to each model el-

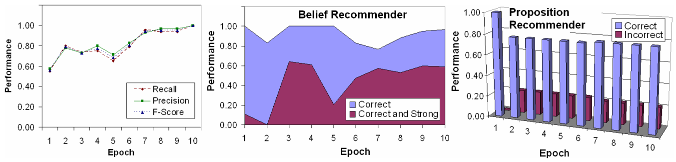

Figure 1. Results of the First Experiment (Class Diagram)

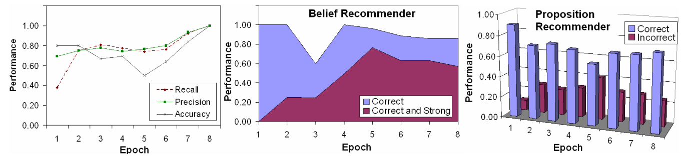

Figure 2. Results of the Second Experiment (State Chart)

ement by the viewpoints (belief recommendation) and also recommends suitable model elements to be added to the individual conceptual models by the viewpoints (proposition recommendation). The proposed model provides the basis for automatic syntactical correctness analysis of the specifications and allows the pruning of the specifications that are not significant from a collective perspective.

3. Experimental Evaluation

Sommerville and Sawyer [4] have proposed three main viewpoints, namely domain, interactor, and indirect stakeholder viewpoints that in their belief can cover most of the aspects of a software design process. These authors also propose four major concerns that need to be considered which are safety, availability, functionality, and maintainability. Following the same setting, we selected different viewpoints that represented these three types of viewpoints. Each viewpoint was given the same textual definition of the Pet Store application. The viewpoints were required to identify the requirements of the Pet Store application from the textual information. According to their own requirement definitions, each viewpoint then designed a UML class diagram and a state chart diagram. They were also asked to initially specify the degree of their own reliability in each of the four concerns.

To support the negotiation, and model integration process, a plug-in incorporated into Eclipse and developed on top of EMF was provided to the viewpoints (Integration Client). A separate plug-in was also developed that managed the server-side processing of information that are gathered from each individual viewpoint (Integration Server). The class diagrams developed by each viewpoint were stored on the server-side plug-in in Ecore format. Using these tools, each of the viewpoints started to specify their requirements and then design their conceptual models. In this process, belief and proposition recommendations were constantly provided to the viewpoints. Furthermore, based on the agreement of the viewpoints the developed conceptual models were merged automatically and stored on the server and the individual models were versioned and also kept on the server. This process was repeated for several epoches (ten for the class diagram development (first experiment) and eight for developing the state chart diagram (second experiment)). In each epoch, the final merged models were compared with a reference conceptual model that had been developed prior to the case study by a set of experienced modelers for the Pet Store application. These reference models were considered as sound models designed based on the given textual information to be compared to; therefore, the aim of the case study was to see if the viewpoints can finally achieve these models (the participating viewpoints were blind to the reference conceptual models).

In each epoch, four metrics were measured, namely True Positive (TP), False Positive (FP), True Negative (TN), and False Negative (FN). TP represents the number of design entities that existed in the reference model and also did exist in the merged model, FP denotes the number of model elements that did not exist in the reference model, but did exist in the merged model. On the other hand, TN shows the number of model elements that did not exist in neither the merged model nor the reference model, and FN depicts the number of elements that did exist in the reference model but were omitted (or did not appear) in the merged model. Using these four metrics, Precision, Recall and Accuracy were calculated.

Figures 1 and 2 show the result of these processes. As it can be seen the precision, recall and accuracy rates of the merged model increases gradually until the model reaches the fully correct state in the last epoch. This shows that the proposed framework consisting of the merge model, reliability evaluators, and belief recommenders are able to formally guide the viewpoints through the conceptual modeling process and enable the viewpoints to form consensus and develop a correct final product. Furthermore, each time that any kind of recommendation was made by the integration server to the viewpoints, its correctness was observed and recorded based on the reference model (See Figures 1 and 2).

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