Towards Domain Specific Modeling Approach in Early Warning System

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ABSTRACT

It is of practical significance and great value to design and develop a novel Early Warning System (EWS), which will be used by the personnel of institutions involved in the drinking water delivery governance model of Ireland. In order to help the users of our EWS in representing and codifying their knowledge on the complex coincidences that may drive Water Treatment Plants (WTP) to failures or to hazardous states we propose in this paper a novel approach of using Domain Specific Modeling (DSM) in the domain of EWS for Water Treatment Plants. The novelty of our DSM approach also lies in providing a standalone open source software application rendering profiling of the water utilities, early warning signals, monitoring mechanisms of signals along with capability of assessing the "tendency" of a WTP towards failure, given a set of observed early warning signals.

Keywords

Domain specific modeling, knowledge modeling, safety, early warning systems.

INTRODUCTION

Access to safe drinking water is a basic human right, but this right is not being met universally. At least one third of the population in developing countries and almost one fifth of the global population have no access to safe drinking water. Diseases related to drinking water continue to be one of the major health problems globally. For example, in 2005, 7,960 confirmed cases of cryptosporidiosis were reported in Europe. Ireland with 13.75 and UK with 9.26 per 100,000 cases have reported the highest incidence rates (Semenza, Nicholas, 2007). In the republic of Ireland in particular, during 2007, the city of Galway experienced the adverse effects of having the drinking water contamination due to cryptosporidium parasite caused by human sewage (Bradley, 2007) resulting to at least 180 serious cases of cryptosporidiosis.

The United Nations have recommended that in order to be effective, EWS have to integrate four elements (i) Knowledge of the risks faced; (ii) Technical monitoring and warning service; (iii) The dissemination of meaningful warnings to those at risk; (iv) Public awareness and preparedness to act. Failure to meet any of these conditions can mean failure of the whole EWS (ISDR, 2006). The ultimate aim of our research is to develop a novel EWS for WTP (Dokas, Wallace, Marinescu, Imran and Foping, 2009). For this purpose we are devising a deployment model based on the Software as a Service business model (Foping, Dokas, Feehan, Imran, 2009) and a Domain Specific Modeling (DSM) approach as a means to model the knowledge about the risk faced by the water utilities in the Republic of Ireland. This paper is focused in our work for the development of the DSM language. It briefly describes our approach in utilizing DSM language for EWS in the domain of drinking water safety.

The novelty of our work, which is a work in progress, lies in using DSM approach that will provide the users with a mechanism to model and to represent the knowledge about the risks that are related to water treatment plants effectively. In this paper we are briefly describe the implementation steps of our DSM language and the architectural details of its standalone software environment.

Reviewing Statement: This paper represents work in progress, an issue for discussion, a case study, best practice or other matters of interest and has been reviewed for clarity, relevance and significance.

DOMAIN SPECIFIC MODELING

DSM is the latest approach for designing and developing software systems (Kelly, Tolvanen, 2008). It requires the systematic use of DSM Language to the representation of various structural and behavior aspects of the problem domain in terms of models. The DSM Language provides higher level of abstraction than general purpose modeling languages by specifying solution using the domain models which are closer to the problem domain than to the implementation domain.

In order to develop any DSM language the domain knowledge is of foremost importance. It is crucial to have the involvement of domain experts in order to perform the detail analysis and structuring of the problem domain that is to examine the needs and requirement. To define domain specific modeling language one has to specify its concrete syntax, abstract syntax, and then semantics is designed to define the meaning of the language (Harel and Rumpe, 2004). The abstract syntax defines the concepts of a language and their relationships. The concrete syntax defines the physical appearance of the language, which can be either graphical or textual. The graphical concrete syntax illustrates the graphical appearance of the models and it is often determined by the structure of the abstract syntax. Furthermore, the semantic is used to describe the meanings of the specified models. The rules of the domain can be included as constraints, thus disallowing the specification of illegal or incorrect models.

IMPLEMENTATION DETAILS

Domain Analysis

The definition of DSM language is based on domain concepts that provide set of constructs for building domain specific models and describes there syntax and semantics. This goal is accomplished by the effort of domain analysis. Domain Analysis is an effort to generate reusable domain models representing the concepts and the entities of real world by capturing their behavior, meanings, properties and related constraints. During domain analysis of our specific domain the detailed knowledge is acquired implicitly and explicitly through various sources such as technical documents and knowledge provided by domain experts.

We aim at capturing and reusing experts' knowledge acquired from the domain of WTP operations on hazards and failures in order to specify domain models. The domain models built by the process of domain analysis correspond to the concepts and entities of our specific domain of EWS in WTP as shown in Figure 2. Hence, these models conceptually represents our domain, its behavior, its constraints together with their diagrammatic representation actually facilitates the platform to think closer in terms of EWS in WTP.

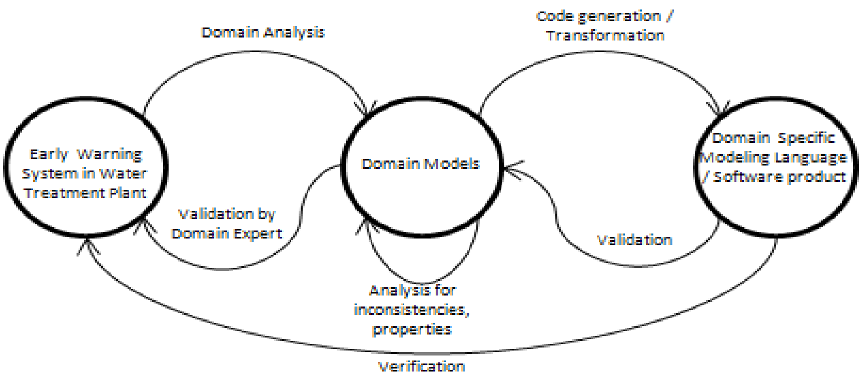

Figure 2: Software development lifecycle using domain models

The effectiveness of our EWS relies on the modeling of adequate knowledge of involved hazards, failures, risks and early warning signals involved in water treatment utilities, which has been achieved by embodying the knowledge of hazards and vulnerabilities in domain models.

Domain Modeling

Domain modeling is a process that is used to raise the abstraction level of concepts belonging into a domain of interest. In model-driven paradigm of DSM multiple metamodels are used to define models. The metamodel is often defined as a model of a model that is the language in which the models are defined. However, metamodels also needs to express in some language, for this purpose we are using model-based Eclipse Modeling Framework (EMF) technology. The EMF is originally based upon a subset of the Object Management Group standard Meta Object Facility 2.0 (MOF) called Essential MOF (OMG, 2006).

For capturing the syntax of the modeling language, a metamodel must describe all the entities and relationships that may exist in DSM (Rational Corp, et. al, 1997). Metamodeling can also be defined as a modeling activity for specifying models by providing object-oriented specification of the abstract syntax, which describes the structure of the language constructs and how they may be combined to create models to be used in domain modeling. The abstract syntax consists of a set of concepts, relationships with other concepts and integrity constraints. The concrete syntax defines the set of notations that facilitates presentation and constructs of the language and might be considered as a mapping of the abstract syntax onto a specific domain of rendering. In short, we can say that the abstract syntax is to define the data structures that can represent our models, the concrete syntax captures how they can be rendered for human interaction.

In order to complete the DSM definition, specifying the domain concepts of EWS in WTP is not sufficient enough as abstract syntax provides little information regarding the concepts and what they actually mean. Hence, the domain semantics is applied to facilitate additional information needed to provide clear representation and meanings. Furthermore, to define the legal relationships between domain concepts and their usage the domain rules and constraints are also required. In this consideration, different kinds of constraints will be applied such as resource constraints will be used to indicate the need for specific resources, integrity constraint to check the integrity of the models itself.

In our approach we have used EMF to relate our modeling concepts directly to their implementation. The kernel of EMF is Ecore metamodels that describe models, relationship among models, and constraints on models. The main elements of EMF Ecore are EClass, EAttribute, EReference (Steinberg, Budinsky, Paternostro, Merks, 2009). The EMF Ecore metamodels are the instances of metametamodel Ecore that has been implemented in EMF. The prototypical set of EWS in WTP concepts for illustrating the Ecore metamodeling implementation with EMF is depicted in Figure 3.

Figure 3: Conceptual architecture of DSM

ARCHITECTURE DETAILS

It is important to provide a modeling environment specialized in a particular domain as well as being able to identify and visually represent the specific domain concepts. In order to provide customized domain specific graphical editor where user can perform computation to assess the likelihood of coincidences that may drive water treatment utilities to failures or to hazardous states we have used Eclipse's Graphical Editing Framework (GEF). GEF provide techniques for creating graphical editor by taking in account existing models specified by EMF metamodels.

In our approach, we stress on providing standalone application, which will be accomplished by building an Eclipse plug-in of our DSM infrastructure embodying EWS methodology and it will further be integrated as a module of RCP. It has been shown in (McAffer, Lemieux, 2005) that this approach is applicable using RCP. By facilitating the RCP platform, the DSM for EWS can run as a standalone application and will allow users to perceive our application as EWS tool for water treatment utilities. Figure 4 shows the higher level architecture of our proposed DSM based EWS application and it also very briefly described.

- Presentation layer: In this layer Eclipse GEF is being used to provide rich graphical user interface for our RCP standalone application. To enable simple changes to be applied to the model from the view GEF employs an model-view-controller architecture

- Logic layer: The logic layer generated by EMF consists primarily of metamodels, representing the entities of the real water treatment utilities as well as with the concepts originating from risk and accident analysis techniques.
- Persistence layer: The Persisting layer handles all the logic to save and retrieve the data from data base. Eclipse EMF Teneo is being used to provide database persistency using Hibernate. The queries on stored EMF objects can be performed using Hibernate Query language.

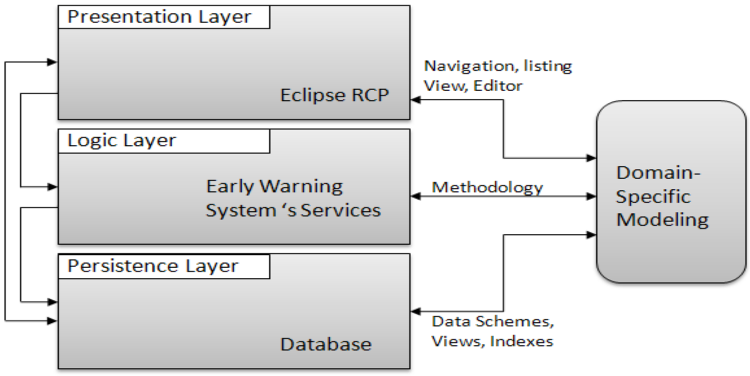

Figure 4: High Level Application Architecture

RELATED WORK

Work related to DSM for EWS in the domain of drinking water utilities can be categorized in two parts: Any previous work on EWS in relation to drinking water utilities and any use of the DSM in EWS.

The literature review found only one example of work undertaken in this area that is the WaterSentinel system (EPA, 2005) developed by the U.S. Environmental Protection Agency, which involves designing, deploying, and evaluating a model contamination warning system for timely detection and appropriate responses to drinking water contamination threats and incidents.

DSM has been successfully applied in a vast array of different domains to create applications for a broad collection of programming languages and platforms including many industrial applications (DSMForum, 2009) such as in insurance sector, mobile phones. The most relevant work found during literature review in regards to deploying EWS has been done on developing a prototyping approach using DSM for describing the earthquake detection algorithms for an earthquake EWS (SAFER Project, 2006).

CONCLUSION AND ONGOING RESEARCH

This paper briefly describes the implementation steps of a DSM language for drinking water utilities. Our innovative approach consists of providing DSM to model the risks and hazards associated to water treatment utilities. However, there are many technical research challenges that need to be resolved to define the early warning methodologies within the drinking water treatment utilities and their deployment in our domain models along with their constraints. These include the modeling of constraints as well as the behavior of the entities of water treatment utilities with respect to the rules and techniques involved in risk management. Further different aspects of DSM implementation need to be investigated such as code generation, improved performance, and validity of the models with respect to the domain.

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