Hypermedia Modelling Using UML

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Abstract: This paper discusses an approach to hypermedia modelling using the Unified Modelling Language (UML). We describe hypermedia models based on four established views of hypermedia system: application domain model, navigation model, presentation model and user model. The approach emphasises UML state diagrams as capable technique for navigation modelling. We relate our approach to other types of models. Adaptation modelling according to the user model is also presented.

Keywords: hypermedia modelling, behavioural model, UML, personalised hypermedia.

1 Introduction

The paper presents an approach to hypermedia application modelling using the Unified Modelling Language (UML). Hypermedia application is considered as a system, which provides information related to particular domain. Presented information is divided into chunks interconnected by active links. To provide comprehensive and consistent model of a hypermedia application, several modelling perspectives were established [4]. Principal perspective is concerned with characteristics of solution (hypermedia) environment, i.e., "what is modelled in hypermedia application" question is resolved. According to this point of view we distinguish:

- *application domain model:* incorporates concepts with their mutual relationships in particular domain. This model determines, which information will be provided by hypermedia application;
- *navigation model:* defines a way, how application will navigate a user in the information net. Navigation model groups information chunks into contexts and interconnects them by links;
- *presentation model:* is concerned with appearance of information chunks to a user. It also defines spatial layout and content of information chunks related to the user interface. Presentation model defines presentation classes or objects, spatial relationships between them and content associated with them.

To support personalisation a *user model* should be incorporated. The user model determines user roles and features, which are important for adaptation and personalisation.

Mentioned views are gradually refined from requirements to implementation.

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Several approaches to hypermedia modelling appear in the literature. Most of them consider all mentioned views in modelling. Differences are primarily in modelling techniques and corresponding notations used together with aspect (structural or behavioural) considered in the process of hypermedia application modelling.

Hypermedia application is an interactive system where reactive behaviour of the application is important especially in navigation and presentation views. Existing approaches employ largely structural models and use E-R diagrams (e.g., Hypermedia Design Method (HDM) [11], Relationship Management Methodology (RMM) [14], Web Modelling Language (WebML) [2]), or class diagrams (e.g., UHML (extended UML by Nora Koch) [12], W2000 (successor of HDM) [1], Object-Oriented HDM (OOHDM) [15]). Behavioural techniques such as petri nets or state diagrams are underestimated and are not widely used. Petri net based model is defined for example in [10]. However, we did not find any design method, which includes it. OOHDM [15] mentions navigation transformation model, which is expressed by Harel state diagrams. It is very similar to Hypermedia Model Based on Statecharts Method (HMBS/M) [3] where both contents and navigation instance schema are modelled by a state diagram.

We proposed UML statechart based approach to navigation modelling in [5] and adaptive navigation modelling in [6]. We believe that behavioural models are crucial for hypermedia application modelling in all its aspects (not only navigation). On the other hand, structural model is also effective vehicle for expressing particular view on the hypermedia system. The goal of this paper is to address modelling approach where behavioural statechart based navigation model plays important role besides the structural models.

The rest of the paper is organised as follows. The application domain model is described in Section 2. Section 3 is devoted to navigation modelling. In Section 4 we discuss how a user model can be expressed by the UML. Next, in Section 5, the presentation model is discussed. The paper concludes with our conclusions and some remarks for the future work.

2 Application domain modelling

All known approaches to hypermedia modelling start with some kind of application domain modelling. Main element for modelling application domain structure is a concept. Concepts are connected by relationships such as association, generalisation/specialisation, and aggregation. Concepts can have their features.

OOHDM, HMBS/M, W2000 and UHML denote application domain modelling as conceptual design and express domain model by a class diagram. W2000 uses a UML class diagram and entitles application domain modelling as information structure design. HDM and WebML use E-R diagram for domain modelling. RMM denotes application domain model as relationship management data model and uses extended entity-relationships diagram for modelling.

We use UML class diagram for conceptual modelling in application domain modelling. We also recommend to use activity diagrams for modelling activities in application domain. A concept is expressed in the UML by a stereotyped class element *Concept*. Features are expressed as attributes or methods, operators and procedures. The basic structural relationships are generalisation/specialisation, containment or aggregation, and general association. Another mechanism to express containment is the package mechanism.

Figure 1 shows an example of simple application domain model. The modelled application is intended to provide information from the subdomain of Software Engineering — Requirements Engineering. For space limitations we restricted the concepts only to higher level of abstraction and taken into account only part of the mentioned domain. Cardinalities of relationships are not important in this context. Requirements engineering domain is modelled from requirements engineering process point of view. *Requiremts Engineering Process* concept aggregates concepts, which represent activities of requirements engineering. *Requirements Elicitation* concept is associated to *Requirements Sources* and *Elicitation Techniques* concepts. Requirements engineering process can be represented by different *Process models*. Each process model can be managed and supported differently and each can differently impact quality of requirements engineering. The activities from these models can be preformed by different process actors.

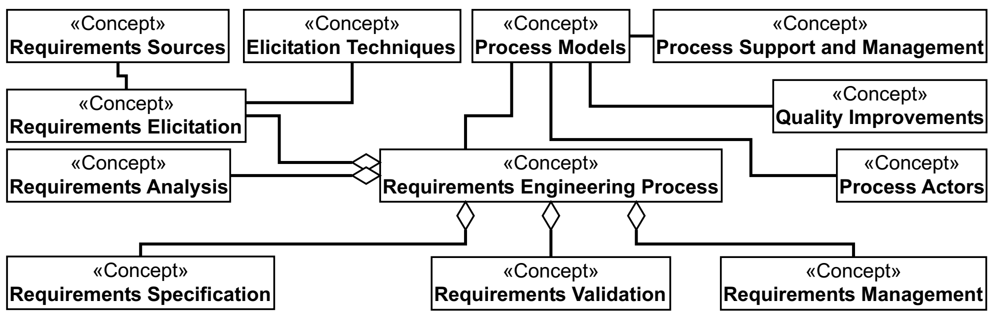

Fig. 1: Conceptual model for requirements engineering according to [13].

Application domain model refinements lead to a database schema for the hypermedia application. The content is then assigned directly to the database schema.

Behavioural model of an application domain can be built too. This model comprises activities related to the domain. The UML activity diagram is used for these purposes. Activity model is useful when hypermedia application should present information about some activities. This model can serve as a base for navigation, e.g., information is presented in order to activity performance. Activities are taken from the conceptual view where they are expressed as concepts.

3 Navigation modelling

Navigation in hypermedia application reflects problem of a user orientation (local or global) in huge amount of information. Navigation problem (lost in hyperspace) can be reduced by appropriate composition of information chunks into information components and adequate interconnection between them. Creating a navigation model, i.e. modelling selection and grouping related information into nodes and their interconnection by links, would highly support the process of hypermedia application development. Composition of related information can be achieved by a query over the conceptual model. This requires some kind of query language over conceptual model. Another possibility is to map required part of conceptual model into the navigation model. Special type of mapping is instantiation.

Approaches to hypermedia modelling mentioned in the introduction use different techniques for navigation modelling. For example OOHDM distinguishes two types of navigation model: navigation class schema and navigation context schema. Both are modelled by structural techniques. In the navigation class schema, nodes and links are used as stereotypes of a class and an association. Nodes group related classes from the conceptual schema and links interconnect them. Navigation context schema is expressed by special notation, which defines collections and access primitives to navigation classes. UHML and W2000 model navigation similarly but using UML or own notation. WebML denotes navigation view as hypertext model, which comprises composition model and navigation model. Composition model is counterpart to context schema. Navigation model defines interconnections between components. RMM and HDM use slices for defining contexts and perspectives over entities. They also provide several access structure modelling primitives such as index, guided tour, etc.

Our approach is based on mapping the class diagram of domain model into the navigation model. Navigation model is represented by the UML state diagram. The intention is to model navigation through concepts appeared in the conceptual model. Concepts and their mutual relationships are transformed and mapped to states and transitions. This state diagram usage slightly differs from original semantics of state diagram in UML where it is assigned to class, use case, operation, subsystem, actors, or method. Details about this mapping can be found in [6]. State transition is raised by events, which mostly appear as a result of interaction of the user with hypermedia application. Accordingly, the first step in creating a navigation model is reasoning about high level interaction scheme. This is modelled by a sequence diagram (example can be found in [5, 6]).

Example of a state diagram is depicted in Figure 2. The guidance is illustrated in three themes: *Requirements engineering overview*, *Elicitation techniques*, and *Supporting Features*. The overview of requirements engineering contains four topics: *Introduction*, *Compositions of main activities*, *User* and *Requirements engineer* represented by states. The guidance in navigation (denoted also as browsing semantics [5]) is specified with the next link (transition). We use the history symbol (H) to indicate that the user is taken into the same state as he was before exiting the system.

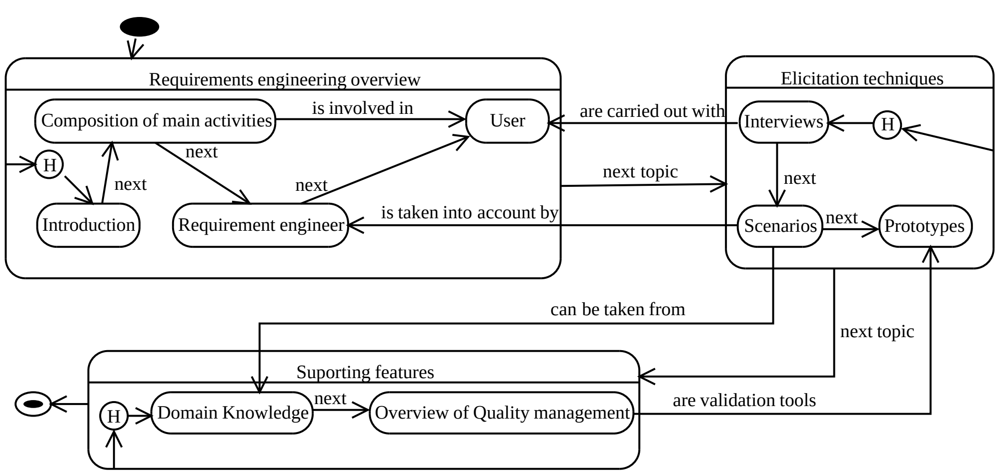

Fig. 2: An example of navigation model for requirements engineering lecture.

4 User modelling

Information is presented to different users. The users often have different goals, preferences and level of knowledge about corresponding concept or set of corresponding concepts. User modelling is employed only in few current approaches. It is mostly because personalised and adaptive hypermedia are relatively new research topic. Rules for adaptation can be defined for example in WebML or extended RMM. User model is employed in UHML using a class diagram.

The user model includes various characteristics of the user: user's goals/tasks, interests, knowledge, background, hyperspace experience, and preferences. There are several possibilities how to express these characteristics. We took as an example the user model, which is used in the adaptive hypermedia system, developed by De Bra et. al. [16]. We represent the structural characteristics of the user model by a class diagram (see Figure 3). The most detailed characterisation of the knowledge is its measuring for each user in each concept. However, this is not always the intent to have such a fine grained measuring. In such case, the knowledge is measured at higher level concepts.

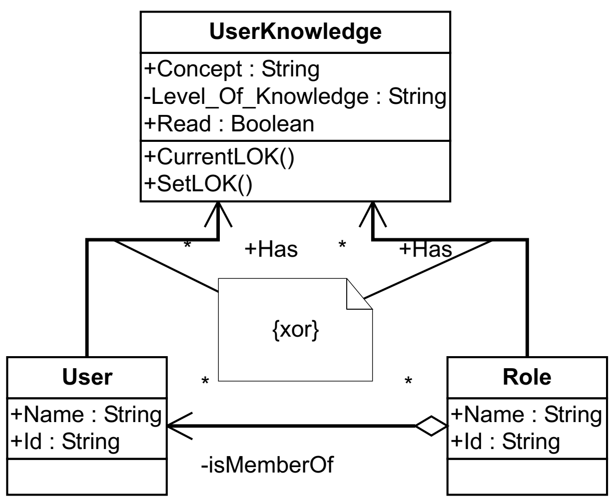

Fig. 3: An example of user model for e-lecture.

Sometimes the structural view is not enough to model tracking of user level of knowledge, his goals and preferences. Within a complex domain with many relationships, we propose to express the tracking of the user model by behavioural model. A state machine is used for expressing the states or levels of knowledge and transitions between them (e.g., when the preference or goal is changed).

5 Presentation modelling

The model of presentation should reflect following characteristics: presentational form for information (font styles and colour, background colour, etc.); arrangement of the information chunks within the interface of the system; the way of the interface change according the user interaction with the system. Adaptive presentation modelling is based on rules for adaptation according to the user model or implicit rules, which do not depend on the user model.

Presentation models are mostly expressed by structural techniques. For example, OOHDM employs advanced data views; WebML uses style sheets for modelling presentation; UHML defines special stereotypes for classes. In [9], RMM is extended with presentation diagram. This diagram represents hyperspace as nodes, which can be composed and connected by three types of links: spatial, temporal and navigational.

In order to model a presentation we refined state machine developed within the navigational model by incorporating additional states (alternative or parallel), which represents different form of presentation for information. Rules, which express the adaptation according to the level of user knowledge are modelled by guards, conditions, and action of states and transitions. For example, considering the navigation model from Figure 2, the presentation model extends the *Domain Knowledge* state with two possible presentation states: *definition* and *detail description*, which appear according to the level of user knowledge about this concept (see Figure 4).

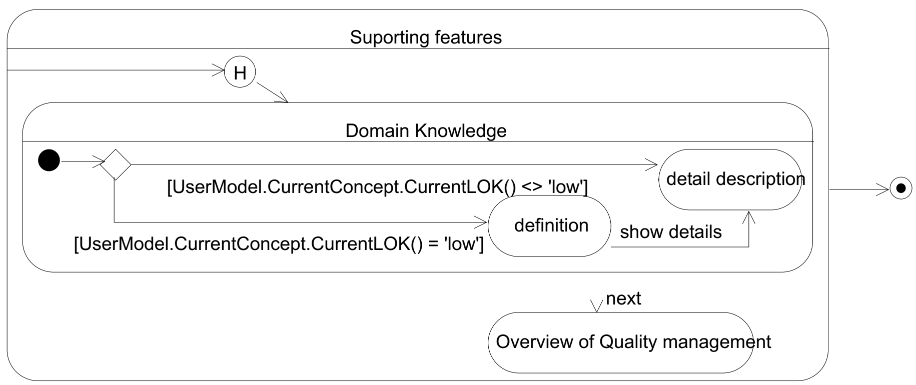

Fig. 4: A part of an adaptive navigation model for e-lecture.

The transition to the *detail description* state is labelled by the condition and corresponding action:

$$[UserModel.CurrentConcept.CurrentLOK() <>' low']/Display()$$

Next extension is setting the level of user knowledge after leaving a composite state:

$$nexttopic[UserModel.CurrentConcept.CurrentLOK() <>' low']/$$
$$Display(); UserModel.CurrentConcept.SetLOK()$$

The transition is labelled by three parameters: received event, guard and effect (action expression). First part is the next topic event. The guard condition related to the current level of the user knowledge is followed by the sequence of two actions that display related knowledge and set the new level of the user knowledge. The presentation model is interconnected with the user model by using the behavioural features `CurrentLOK()` and `SetLOK()` of the *UserKnowledge* class.

Special characteristic of a hypermedia system is that different media types are involved in. The concurrently presented media types have to be synchronised when they present relevant information. In our approach we model the channels [7] in presentation by composite states. The concurrent synchronised media channels are modelled by concurrent state and for synchronising these channels the synchronisation symbol is used (synchronisation or fork and join pseudo-metaclasses). All mentioned modelling elements are included in the state machine package of the UML.

Static presentational characteristics of classes or objects can be modelled by adding presentational structural features. Another possibility is to create new stereotype of class for presentation templates. These templates can be then mapped to particular states. We proposed and realised such solution in a system for creation of structured documents and annotations of their parts on the web [8].

6 Conclusions

We described the possible usage of UML for modelling of hypermedia application. We believe that state diagrams are better suited especially for personalised or adaptive hypermedia application modelling as techniques for structural modelling. The transition between states is semantically closer to an interaction based information change at the user interface. Structural techniques for navigation modelling use association or its stereotypes. This type of relationship is rather for modelling of static aspects of a system. Moreover, adaptation brings even more dynamics to the navigation.

In spite of this, static aspects of navigation modelling are also useful. As we mentioned, state diagrams are used only in HMBS/M and OOHDM but at the instance level. We allow to map also classes to states and relationships to transitions or state's decomposition. In addition, OOHDM and a lot of guidelines based on it recommend to use only structural techniques where only one "default browsing semantics" can be derived. However, this is not enough for interactive adaptive hypermedia application modelling where several browsing possibilities have to be considered for different users. Direct refinement of navigation model based on a state diagram can serve as the presentation model (different alternatives for content).

Further presented modelling techniques are used also in various existing methods for hypermedia development. Navigation modelling approach proposed in this paper requires different mapping rules between these techniques and the navigation model. Figure 5 depicts high level dependencies between models. These dependencies can be considered as a base for mentioned mappings. We are now working on precise definition of transformation of mentioned models from analysis to implementation.

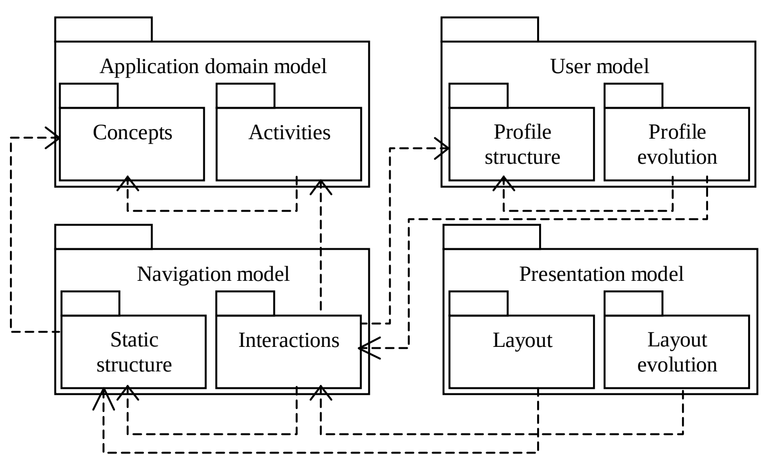

Fig. 5: High-level dependencies between hypermedia models.

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