Volume 2 No. 1, January 2012
International Journal of Information and Communication Technology Research

http://www.esjournals.org

An Extension of UML Modeling for Web Hypermedia Design: A Case Study

Azrul Hazri Jantan
Faculty of Computer Science and Information Technology, Universiti Putra Malaysia
Selangor DE 43400, Malaysia.

ABSTRACT

It is obvious that the design efforts taken in modeling web hypermedia application are significantly different to basic web information systems. The designs should emphasis on domain structure, complex processes and interactions, functions and operations, hyperlinks structure, and logical abstract presentation designs. This paper present and discuss the design of a web hypermedia application – a case study, called SLEX-Web application. It is a web hypermedia application of a faculty in university environment that offers general information and learning application to its users. The existence of complex processes and interactions are highlighted and taken as examples to present some of complexity issues arise in the design efforts. The main objective is to describe how those processes and interactions should be treated, modeled, and translated into user interface elements through the major design processes. A systematic UML-based design method, called Com$^+$HDM is used as the medium of design approach and notations. Finally, this paper will summarize the design efforts by giving some arguments, lessons learned, and conclusions at the end of the paper.

Keywords: *Web Hypermedia Application, Design Processes, UML Notations, Navigation, Interaction, User Interface Elements.*

1. INTRODUCTION

To date, web hypermedia applications have evolved in its scope and become as one of the best approaches to provide information to web users. The effort of designing and developing these applications therefore, have raises a number of design issues on hypermedia modeling activities [1]. Some design issues have been encountered by many researchers, such as modeling complex business processes, navigation access structures, activities and transactional workflows, user dependent processes, and so on [4,5]. To cope with these issues, several hypermedia design methods with different design features and modeling concepts have been proposed such as Object-oriented Hypermedia Design Method [6], Website Design Method [7], UML-based Web Engineering [9,12], and Object Oriented Hypermedia [11,12]. However, many practitioners believe that more design efforts are required to take place for supporting a different way of dealing complex web hypermedia applications, perhaps in a more comprehensive and systematic design aspects. One of the major ways is to provide suitable modeling elements and facilities through the design processes. There are two issues to be reviewed in this paper, complex processes and complex interactions. Complex processes can be defined as processes that can be nested or comprise of set of sub-processes, processes that can be suspended and resumed again, and processes that should be synchronized to their predefined activity sequence. Some of their limitations have been discussed in previous works [2,3]. On the other hand, complex interaction holds different scope of definitions. It concerns on navigation elements for web users to browse web page or executing operations. It describes how web users deal with the application through the navigation facilities [3]. According to these complex issues, this paper will focus and discuss the design of a web case study through the uses of design method for supporting various structures of complex processes, information and interactions, navigational preferences, access elements, and user interface presentation.

This paper is organized as follows. Section 2 will briefly describe the principles of design processes with two design issues – complex processes and interactions. In Section 3, this paper will provide information on a UML-based hypermedia design method, called Com$^+$HDM. Then, Section 4 will clearly demonstrate the design efforts taken to model a case study, including conceptual design, navigation design, and user interface design. This section will also provide discussions on the modeling elements used, design approach, and models constructed. The summaries of discussions and results will be covered in Section 5. Finally, Section 6 will conclude all research works and findings.

2. PRINCIPLES OF WEB HYPERMEDIA DESIGN PROCESSES

The process of designing web hypermedia application is one of the big challenges for today's web engineering industry. In comparison to information system design, web hypermedia application demands a number of additional design aspects including on its complex domain structures, information contents, various interactive operations and functions, navigation links and access mechanisms, and presentation layouts [13]. Thus, web hypermedia design methods have been proposed in the past few years to tackle and support those aforementioned

design aspects [15]. Ongoing research efforts have found that most of the methods are model driven and consist of a number of design processes [8,14]. The effort of these design processes are normally being done in iterative and incremental approach. For each design process, models should be constructed to present the result for the design effort. In the other word, models constructed should able to present higher level descriptions and structures of particular application domain. Some design methods use their own notation for constructing design models, while the others conform to existing standard notations such as Unified Modeling Language (UML) [16].

Generally, design practices involve with several processes paradigms such as conceptual design, navigational designs, and user interface designs [10]. In conceptual design process, designer concentrates on conceptual "what" and "how" to describe information structures in application domain model [9]. It should provide classes, objects, attributes, and associations for the interaction between web users and the application. The result of conceptual design process is presented through conceptual model. It should present and determine which information is made available to web users, including the details. This paper will focus on complex processes design in the context of capturing the flow of processes and integrating them into one specific domain model. The issues of complex processes should be refined to ensure all classes and its contents could be systematically integrated. Upon the completion of conceptual models, navigation scheme are designed and constructed as navigation models. The main objective of navigation design process is to specify how information in conceptual model is presented as navigation classes and inter-connected with hyperlinks. Any design method should able to provide navigation facilities, thus to model navigation structures and links according to the needs from navigation preferences [19]. In general, navigation designs can be performed in two different sub-design efforts, called navigation class scheme and navigation context scheme [10]. In the former, navigation classes are defined according to the constructed conceptual model. It represents navigation nodes that are reachable by web users. These nodes are linked appropriately depending on the suitability and navigation preferences. On the other hand, navigation context scheme is aimed to equip those navigation nodes with access elements. It is to define "how" those navigation nodes are reached by web users with suitable and best appropriate navigation access elements [9]. The final design process is user interface design. User interface model is constructed to present abstract user interface elements – presented through logical views of web hypermedia application, incorporating the layout and visual characteristics of information. User interface elements should be defined through graphical notations before designer can deploy them as user interface objects on particular page layouts [20]. The idea is to locate the elements on page layout according to the storyboard. At the end of the process, user interface models are constructed to present screen layout including their user interface elements and its position.

3. Com$^+$HDM: THE DESIGN METHOD

The central purpose of this section is to describe a systematic UML-based design method, called Com$^+$HDM (Comprehensive Hypermedia Design Method for Complex Process Modeling). It would incorporate comprehensive and systematic dimensions of three design processes – conceptual design, navigation design, and user interface design. In general, there are three objectives on Com$^+$HDM, (i) to model complex processes through its systematic conceptual design and information modeling; (ii) to provide navigation and access structure mechanisms to support process flows and their interactions; and (iii) to present interaction between web users and the application through abstract user interface models. Figure 3-1 illustrates methodological approach of Com$^+$HDM.

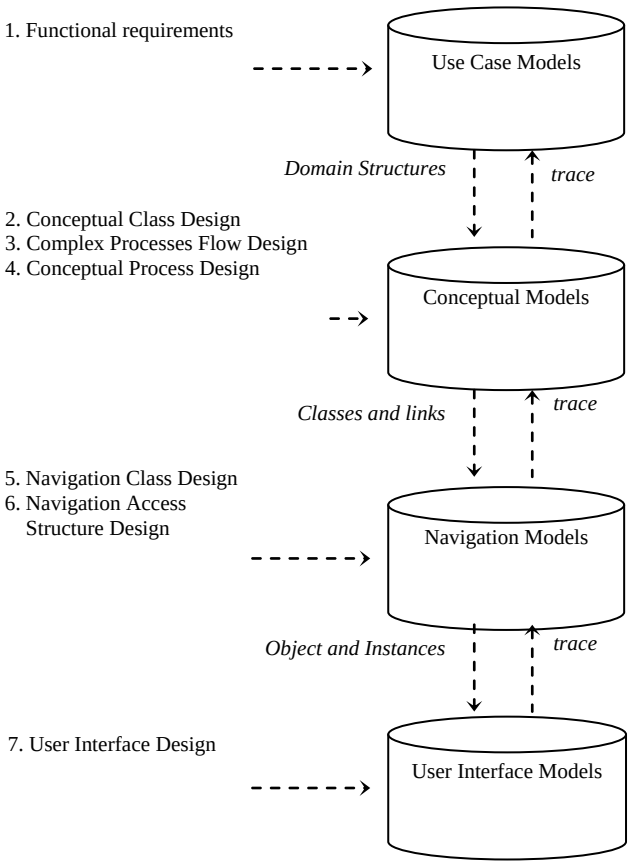


Figure 3-1: Design approach of Com$^+$HDM

Com$^+$HDM can be applied in increment and iterative design fashion to support reusability design principle, leading to a systematic and flexible development lifecycles. It is a generic object-oriented modeling method base on UML modeling paradigm [16]. The design is a model-based approach where models are built in separated

design processes to provide better modular results. Figure 3-2 lists modeling elements (stereotypes) in Com+HDM.

Conceptual Modeling (Conceptual Process Design)	«process class» «atomic class» «non-atomic class» «database class» «process container» «process link» «action link» «database link»
Navigation Modeling (Navigation Class Design) (Navigation Access Structure Design)	«navigation class» «interaction class» «navigation link» «index» «tree » «text Query» «selectable List» «guided tours» «page» «menu» «trail menu»
User Interface Modeling (User Interface Design)	«UI Page» «UI Interaction» «frame Page» «UI Login» «UI Session» «UI Element» «UI Access Structure» «UI Multimedia Element» «UI Form Element»

Figure 3-2: Stereotypes for the Design Models

The main concern of Com+HDM is to support modeling facilities of complex processes including its contents modeling, navigations structure, and presentation layout. It presents several stages of design practices to produce Use Case Models, Conceptual Models, Navigation Models, and User Interface Models. Those models should complement each other to provide specific design inputs and information specifications. Treating them as different design stages will allows designers to put efforts and concentrate on different concerns one at a time. More modular results and reusable design can be captured for every specific design features.

4. SLEX-Web Application: A CASE STUDY

In this section, this paper will elaborate clearly the design processes of SLEX-Web application using Com+HDM. SLEX-Web (*Self-pace Learning with Exercising Approach on the Web*) is a web application that owned by a university's faculty for providing general information, teaching materials, and learning modules for its web users. There are two parts in SLEX-Web application. The first part relates to information about programs and degrees offered by departments, employees' details and profiles, research projects, research groups, and courses offered. The other part focuses on teaching and learning course contents and evaluating students in quiz session. It provides basic learning modules and facilities for students with great possibilities of interaction features. In the context of designing the application, designer should able to model functional operations for supporting complex processes and interactions through navigation facilities. Information should be classified into difference conceptual classes and each class holds several types of attributes and operations. These efforts are then further details to provide higher level presentation of domain structure in models view. Models will represent results of each design process. To avoid models overloaded with too much additional information and unnecessary details, this paper will present some important information only.

4.1 Conceptual Design Process

The main objective of conceptual design is to build models that will describe the structure of application domain. Com+HDM proposed three stages in conceptual design called (1) Conceptual Class Design (CCD); to build Conceptual Class Model (CCM), (2) Complex process Flow Design (CFD); to build Complex process Flow Model (CFM), and (3) Conceptual Process Design (CPD); to build Conceptual Process Model (CPM). In CCD, information contents are identified and captured according to user requirements. The idea is to present information classes through UML Class Diagram, called Conceptual Class Model (CCM). Figure 4-1 shows CCM of SLEX-Web application.

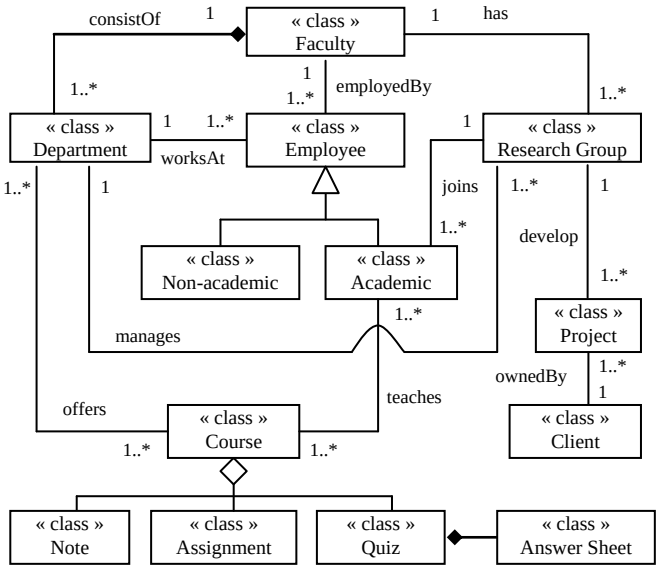


Figure 4-1: Conceptual Class Model (CCM)

CCM provides designers with complete views of information contents and structures of particular application domain. In Figure 4-1, SLEX-Web can be structured into various conceptual classes with their own associations between those classes. The model is equipped with association names, multiplicities, and relationship to

present the details components of each class. However, for the sake of simplicity, we hide their attributes and operations compartments.

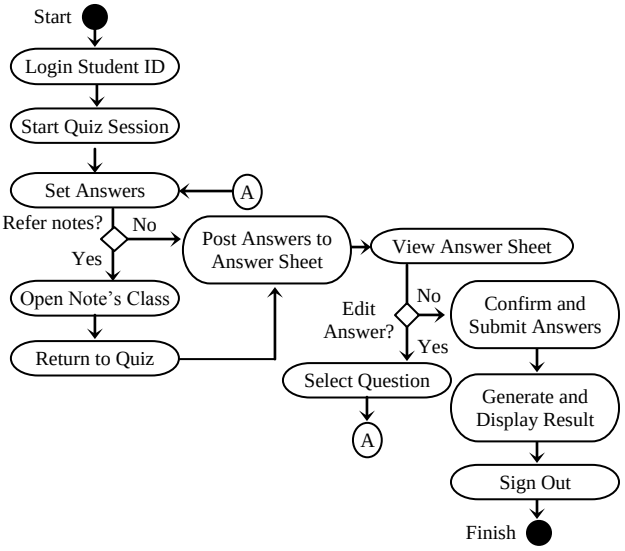


Figure 4-2: Complex Process Flow Model (CFM)

Once CCM has been constructed, flow of complex processes and interactions are captured in CFD. This paper consider examples involving atomic and non atomic processes that underlies under the *Course* class such as processes of viewing note, submission of assignments, and participating quiz session. A standard diagram of UML Activity Diagram is represented as Complex Process Flow Model (CFM) to present the flow of activities performed to achieve certain objectives of processes. Figure 4-2 presents an example of CFM for activities processes in *Quiz* class.

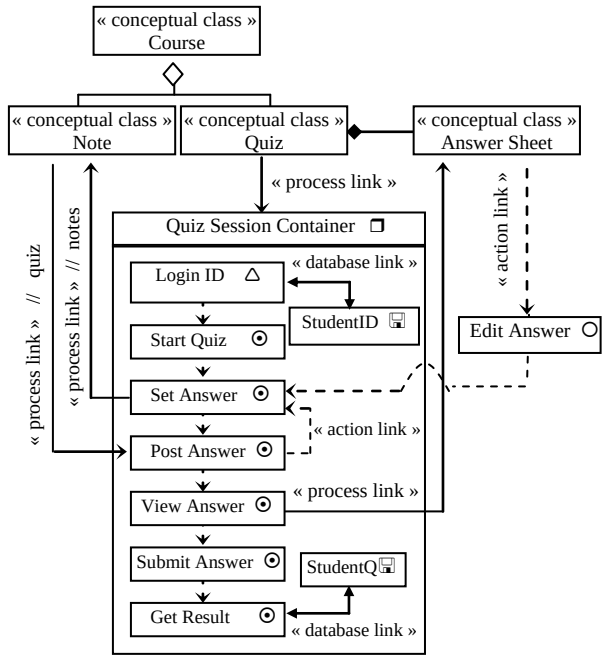


Figure 4-3: Conceptual Process Model (CPM).

Com+HDM proposed new conceptual design stage (CPD), specifically to integrate complex process modeling. In CPD, several specific modeling elements (stereotypes) are provided to facilitate design efforts in the modeling approach (see Figure 3-2). A more detail descriptions about these stereotypes can be found in [2]. The result of the design is presented through Conceptual Process Model (CPM). The construction of this model should trace information from both CCM and CFM. According to the proposed stereotypes, CPM is constructed for each relevant class in the case study examples. Figure 4-3 presents an example of complex processes modeling. In this figure, «process link» reacts as the medium of physical navigation link to support interaction between three conceptual classes – *Quiz*, *Answer Sheet*, and *Note*. On the other hand, activities processes for conceptual classes are interconnected through «action link». This is to present logical interactions that may happened between web users and the applications.

4.1.1 Lesson Learned: Conceptual Models

Conceptual Class Model (CCM) is constructed according to standard UML Class Diagram. All conceptual classes represent application structures and domain of SLEX-Web including their associations, attributes, and operations. These are important as the information will be deeply considered to construct other models in successive design processes. Complex process Flow Model (CFM) is built in order to capture flow of complex processes. They are captured and presented through the uses of standard UML Activity Diagram. The final effort of conceptual design is to integrate CFM into CCM. The main idea is to provide higher level view of structure domain consisting of any related complex processes. Any processes performed in conceptual class can be further details to describe atomic and non atomic processes. In Conceptual Process Model (CPM), designer can view which classes involve with complex processes, how the objectives of processes achieved, in what directions the process flow is performed, what instances or objects are relevant to the process flow, and how those conceptual classes and complex processes can be further enhanced to construct navigation models.

4.2 Navigation Design Processes

The main objective of navigation design is to identify navigation classes, interaction classes, hyperlinks, and access structures elements. Com+HDM separates navigation design into two different processes – first known as Navigation Class Design (NCD) and the other known as Navigation Access Design (NAD). In NCD, designer analyzes conceptual classes defined in conceptual models (more specifically in Conceptual Class Model) within their relevant associations. The idea is to present navigation hyperspace on what information should be

provided to web users. Figure 4-4 presents navigation classes, interaction classes, and hyperlinks in SLEX-Web derived from Conceptual Class Model (CCM) and Conceptual Process Model (CPM). In comparison to CCM, Navigation Class Model (NCM) eliminates *Client* class since it is not much relevant to be part of the navigation classes. However, its attributes have moved into *Project* class as derived attributes. Two examples of interaction classes are given, namely «Handin Assignment» and «Quiz Session». Both classes present interaction activities for submitting assignment and to participate quiz session, respectively.

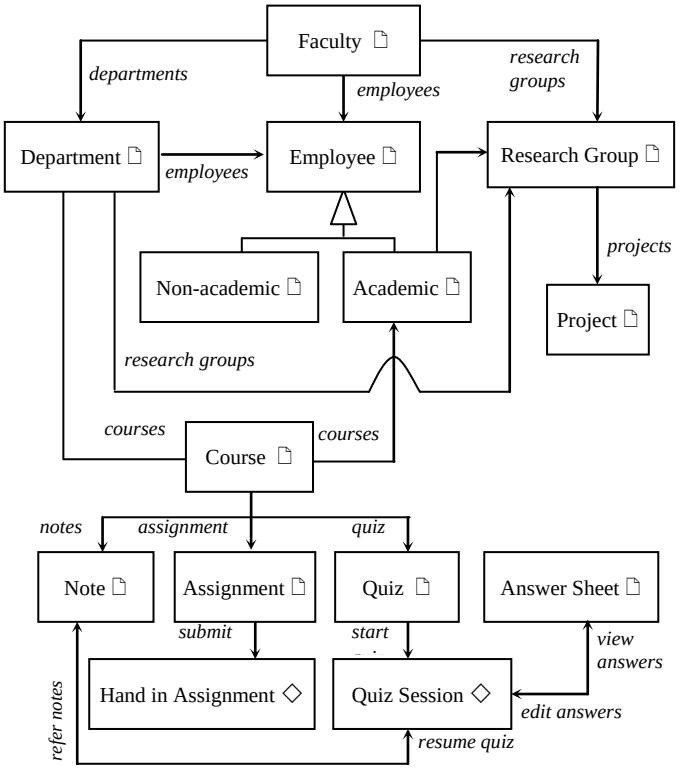


Figure 4-4: Navigation Class Model (NCM).

Navigation classes, interaction classes, and hyperlinks in NCM are then equipped with access structures elements in Navigation Access and Interaction Model (NAIM). The idea is to present how those navigation and interaction classes are reached by web users in the real SLEX-Web. Com^{+}HDM introduced several types of access structures mechanisms such as index, tree, text query, selectable list, guided tours, page, menu, and trail menu (see Figure 3-2). More details on these stereotypes can be found in [3]. NCM is enhanced by providing appropriate access elements depends on navigation requirements and functional suitability. Figure 4-5 presents how access structures elements are included in NAIM according to designer preferences. NAIM presents the complete structures of navigation hyperspace including the access structure elements.

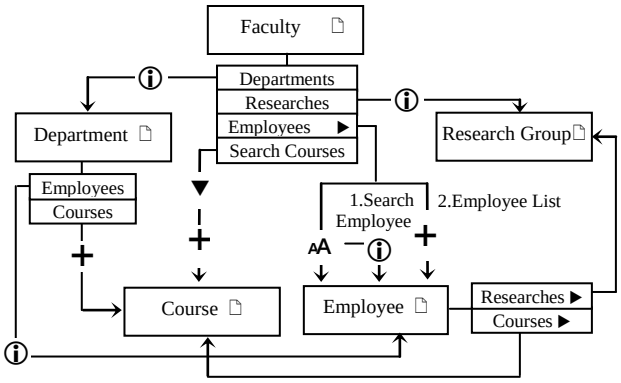
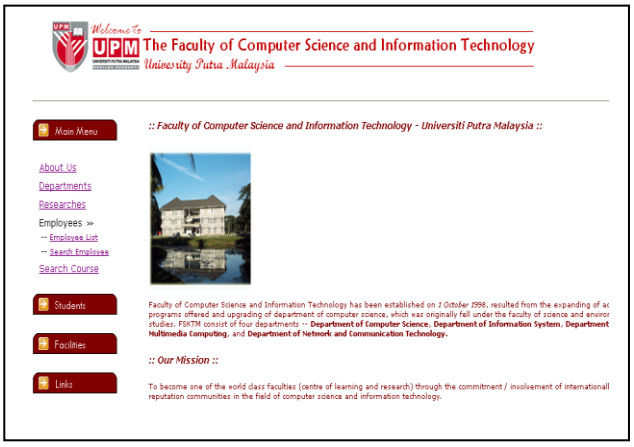
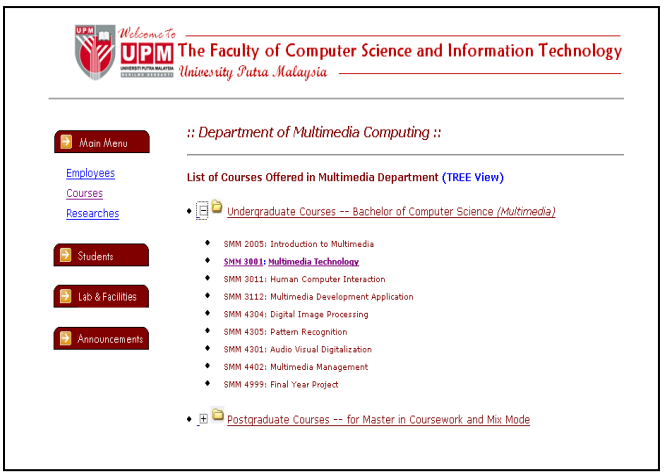


Figure 4-5: Part of Navigation Access and Interaction Model (NAIM) – Faculty as the Home Page.

The home page of SLEX-Web application is assigned as *Faculty*. Figure 4-5 shows there is a list of menu items provided – departments, researches, employees, and search courses. Those menu elements are implemented as shown in Figure 4-6 (on the left hand side of the page).



Menu provides navigation links to associate navigation nodes such *department*, *employee*, *course*, and *research group*. A trail menu called *employee*, is also provided. There are two items on the trail menu; *employee list* and *search employee*. These items can be expanded or collapsed according to user input, thus trail menu can reduce the cost of time and page space on the web. Another example of access structure mechanism is given in Figure 4-7. In this example, a tree structure is provided in *department* node to find courses via menu element. Tree provides suitable access structure element if it contents several numbers of objects or instances. Figure 4-7 presents several numbers of courses offered by department in tree presentation. Page layout could be kept neatly, access time to navigation target node is lessened, and user's orientation on searching information is better.



Com+HDM also introduce interaction class in both NCM and NAIM (see Figure 4-4). The idea is to describe interaction processes performed by users to achieve particular objectives. Figure 4-8 presents another NAIM's example of SLEX-Web application to describe interaction classes – *Hand in Assignment* and *Quiz Session*. The details description about processes flow in interaction classes are described in CPM. In the context of navigation design, Com+HDM concerns interaction class as a class that contains processes with objectives, transaction flows, interactive feedbacks, application processes, and scenarios that depends on actions triggered by users. Figure 4-9 presents how interaction class – *Quiz Session* is implemented in SLEX-Web application. Each user is required to login before participating in the Quiz Session.

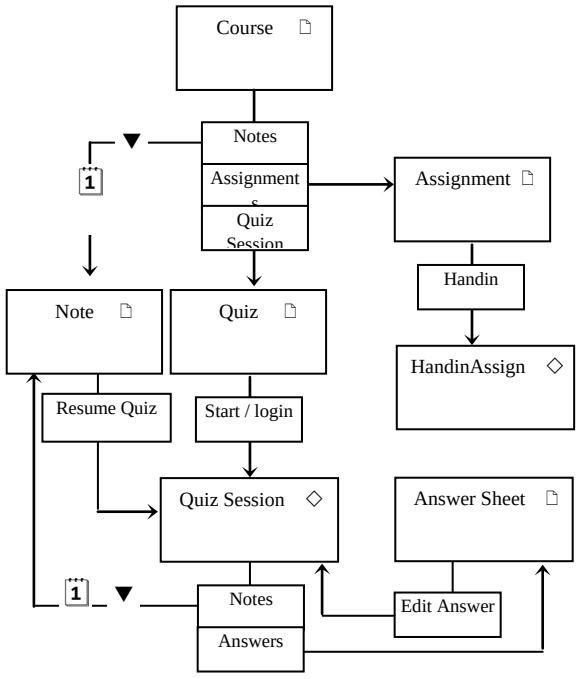


Figure 4-8: Part of NAIM – Interaction Classes of Hand in Assignment and Quiz Session.

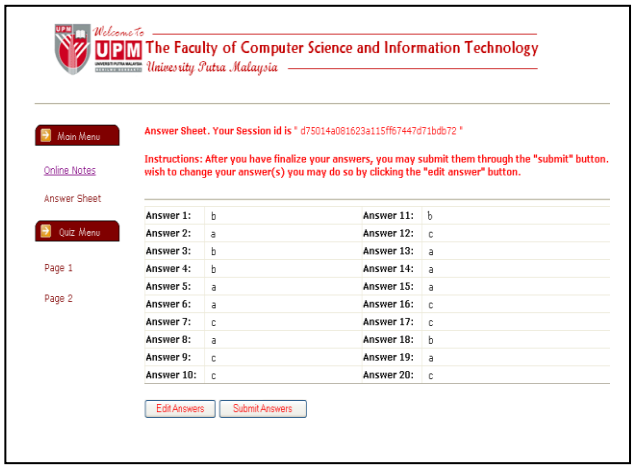


Figure 4-9: Quiz Session

After login process was successfully passed, users can start the quiz session by answering questions and posting their answers to answer sheet class till the end of the session. While answering questions, users can navigate to note class. These processes are performed until users have completely filled the answer sheet. If users intend to change answers from answer sheet, they can perform that by clicking edit answer button. If they satisfied with the answers, they can submit them and the application will generate the results.

4.2.1 Lesson Learned: Navigation Models

This section has demonstrated how navigation design is conducted. Com+HDM provides the design with four UML-based stereotypes – navigation class, interaction class, hyperlinks, and access structures. All stereotypes are derived from conceptual models except access structure elements. The design and implementation of access structures are basically depends on designers' preferences. There is no automatic generation way on how access structures can be perfectly defined. In short, navigation class is defined as navigation node; interaction class presents interaction between users and application; hyperlinks describe navigation paths; and access structures present how navigation nodes are reached by users. The design models – Navigation Class Model and Navigation Access and Interaction Model are further enhanced to generate page layout design for real presentation through the uses of mapping rules formulation.

4.3 Abstract User Interface Presentation

The main objective of User Interface Design (UID) is to provide page layout presentations of SLEX-Web application. This effort is done by transforming all navigation objects captured in navigation models to user interface objects through mapping rules transformation. Table 4-3 presents mapping rules formulation between navigation objects and user interface elements

Table 4-3: Mapping Rules Formulation

Navigation Objects	*Map to* – User Interface Objects (Stereotype)
«navigation node»	«UIPage» → «framePage» → «UIElement»
«interaction node»	«UIInteraction» → «framePage» || «UILogin» → «framePage» || «UISession» || «UIElement»
«navigation link»	«accessStructure» || «hyperlink» || «formElement»
«access structure»	«UIElement» → «accessStructure» || «multimediaElement» || «formElement»

These mapping rules provide designers with easy and straightforward formulation on how particular objects defined in navigation models can be translated as user interface objects. The results of UID are presented as User Interface Model (UIM). This paper provides an example on how Com$^+$HDM formulates mapping rules conditions to generate *Employee* page layouts. The implementation of this page layout is employed with high fidelity prototyping approach via computerized-based web tools. According to Table 4-3, *Employee* navigation class should be translated according to the mapping rules for «navigation node» stereotype. At the beginning, the mapping rules should transform a navigation node as a User Interface Page «UIPage». It represents a page layout of a web page. Then the web page is partitioned into a number of Page Frames «framePage». This effort depends on the designer preferences. For each page frame defined, it should able to hold several User Interface Elements «UIElement». Figure 4-10 presents the example of Employee page layout:

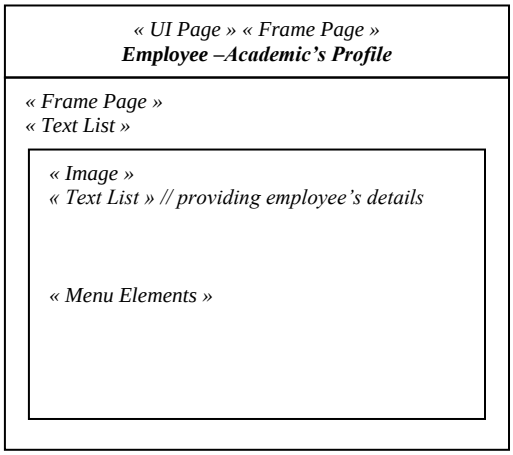


Figure 4-10: User Interface Model for Employee's page.

The web page should contain information such as name, department, address, contacts, etc. Those information is located exactly where the logical presentations of their page layout in UIM (as shown in Figure 4-10). The design of physical presentations like color, size, and appearance are beyond of the scope of this study. Finally, information in the UIM is translated into the real implementation of web tools through relevant user interface elements.

Figure 4-11 illustrates the implementation of physical presentation of *Employee's* page.

Figure 4-11: Implementation of Employee's Page.

All user interface elements are implemented according to the design of UIM as shown in Figure 4-10. Note that the physical page layout is implemented according to the interface preferences of web developer.

4.3.1 Lesson Learned: User Interface Models

The mapping rules give significant guidelines for designers on how transformation could be applied between objects in navigation models and user interface models. In the other word, these mapping rules react as the medium of translating different conceptual and navigation objects to be represented in the form of user interface objects. The idea is to present presentational page layouts from information identified in navigation structures and access structures mechanism into user interface elements. User Interface Model (UIM) constructed provide high-level abstract overview of how various pieces of information and navigational objects positioned onto screen layout and accessed by web users. Com$^+$HDM however, scopes the modeling efforts into structural models only, which imply that the presentation of user interface objects only consider logical characteristics, not the physical aspects. UID specifically capable into presenting user interface layout, in the context of general information contents defined in both conceptual models and navigation models; specifically to support on its complex processes, interactions, and access structure mechanisms. For each UIM, web developer is responsible to implement those presentation requirements successfully according to his capabilities and creativities.

5. DISCUSSIONS

This paper has clearly described the design and implementation of a web case study using a systematic UML-based hypermedia design method called Com+HDM. This method has successfully demonstrated to support and design internal structures of web hypermedia application, including those that involved with complex processes and interactions. Besides, Com+HDM can be used to design web hypermedia applications through its comprehensive design views and fit all specific modeling elements (stereotypes) in an effective way. From conceptual models to user interface models, those proposed stereotypes complement each other in a systematic way in order to provide designer with flexible and dynamic contents of numerous descriptive and restrictive properties. In addition, Com+HDM defines information requirements from Use Case Models such as functional and non functional requirements to derive all information into conceptual domain that either has a single class or multiple classes with numerous associations, in which web users can access those associative links through navigation links. Conceptual and navigation classes are then mapped into user interface objects where abstract logical presentations are provided as the idea of storyboarding the web pages. In overall, the following are the summaries of the design approach discussed:

- The implementation of SLEX-Web has demonstrated the importance of having the right and appropriate design efforts and modeling guidelines to support design and development practices effectively. Com+HDM is a systematic design method that promote comprehensive modeling features in particular web applications.
- Com+HDM provide comprehensive and detail structured design views, including conceptual domain, navigation structures, and abstract user interface presentation. Within these design views, it is agreed that the design features capable to offer adequate and effective modeling elements not only to present the design models, but at the same time it could also support the dynamic design practices for elaborating internal domain structures specifically on complex processes and interactions in the application.
- Com+HDM supports and fulfills the requirements of hypermedia design dimensions, namely application contents, content's structure, user interface, dynamic, and interactions [21,22]. The details structures of design models in the case study examples prove the internal strength of the design concepts. Table 5-1 presents how Com+HDM design models reflected to the hypermedia design dimensions:

Table 5-1: Com+HDM Design Models in Relation to Hypermedia Design Dimensions

Design Dimensions	Com+HDM Design Models
Application Contents	Conceptual Class Model Conceptual Process Model
Content's Structure	Conceptual Class Model Navigation Class Model
User Interface	Navigation Access and Interaction Model User Interface Model
Dynamics	Navigation Class Model Navigation Access and Interaction Model
Interactions	Complex Process Flow Model Conceptual Process Model Navigation Access and Interaction Model

Table 5-1 describes how Com+HDM support all design dimensions according to the implementation of SLEX-Web application. Each model constructed in the design processes is considered as evaluation subjects to provide input and descriptions on the design features in relation to design dimensions. The modeling concepts which supported with various forms of precise and expressive modeling elements make possible for designer to model application in a successful way.

6. CONCLUSIONS

An implementation of SLEX-Web case study has been taken into consideration in this paper to demonstrate how design efforts in Com+HDM are applied in the real design practices. It provides a systematic way on how specific modeling elements or stereotypes applied into the design through its unique properties. It promotes usability design aspects of web hypermedia applications due to the disciplines that it encourages during the design processes. In the case study, SLEX-Web application consists of several complex processes that provide interactions between web users and application. From the constructed design models, it is observed that the modeling techniques offered in Com+HDM could provide essential and expressive modeling elements to support the design of higher level views of domain structures. Com+HDM is a UML-based approach, no parts in the design processes seem to be difficult and hard to model – the end result of each design process was not too complex and easy to understand. Furthermore, design processes are separated and they only dealt with small part of the whole designs. However, design models constructed should complement to each other in order to trace information from one model to another. To conclude, models constructed from design processes (conceptual, navigation, and user interface) made it easy to visualize the contents of application domain, its navigation structures, and web pages layout – and yet they are all expressive and intuitive to implement.

ACKNOWLEDGEMENT

The author would like to acknowledge the funding support for this project from the Research Management Centre (RMC), Universiti Putra Malaysia, 43400 Selangor DE, Malaysia, under the grant of Research University Grant Scheme (RUGS) – Project 05-01-11-1249RU. The author would also like to thank the anonymous reviewers for their valuable feedbacks and comments.

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