

**A SYSTEMATIC DESIGN METHOD FOR MODELING
COMPLEX PROCESSES AND INTERACTIONS
IN WEB HYPERMEDIA APPLICATIONS**

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UNIVERSITI SAINS MALAYSIA

2009

**A SYSTEMATIC DESIGN METHOD FOR MODELING
COMPLEX PROCESSES AND INTERACTIONS
IN WEB HYPERMEDIA APPLICATIONS**

By

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**Thesis submitted in fulfillment of the requirements
for the degree of
DOCTOR OF PHILOSOPHY**

December 2009

ACKNOWLEDGEMENTS

Al-Hamdulillah (*Segala Pujian Hanya Bagi Allah*) ...

Three years ago, I would never think that I should ever write a doctoral thesis. It seemed really tough enough and impossible for me to complete this research study, ever. But now, everything is done. A thousand smiles and special thanks to a large number of people out there for their supports, assistances, ideas, and inspirations, during the completion of this research study and writing of my doctoral thesis. My particular thanks go to:

(1) Prof Madya Dr Putra Sumari and Dr Shahida Sulaiman – supervisor and co-supervisor, with constant motivational supports, immense assistance and guidance, and great encouragement all the way upon the completion of my thesis and research successfully. (2) Dr Vincent Khoo Kay Teong (Internal Examiner 1), Dr Yap Fa Toh (Internal Examiner 2), and Prof Madya Dr Nor Adnan Yahya (External Examiner). Thanks for your time and efforts with patience and interests for going through all the time of thesis reading and stimulating academic discussions on viva session. (3) Ministry of Higher Education of Malaysia and Universiti Putra Malaysia – the main sponsors of my study. I gratefully acknowledge the funding and sponsorship that helped providing sponsor for this research study.

And finally, I am most indebted to all my relatives and friends, especially to my parents Haji Jantan Kesit and Hajah Azizah Ibrahim, my daughter Aisyah Izzati, my siblings Azrul Azlan, Mohd. Afiq, and Siti Nuramira, and to all of my dearest friends for being there to put me up and up with continuous moral supports. Thanks guys ...

“Jazakallahu Khairra...”

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LIST OF ABBREVIATIONS

| | |
|----------------------|--|
| ADM | Adriane Development Method |
| APD | Abstract Presentation Diagram |
| CCD | Conceptual Class Design |
| CCM | Conceptual Class Model |
| CFD | Complex Process Flow Design |
| CFM | Complex Process Flow Model |
| CLD | Composite Layout Diagram |
| CPD | Conceptual Process Design |
| CPM | Conceptual Process Model |
| Com ⁺ HDM | Comprehensive Hypermedia Design Method |
| ER | Entity Relationship |
| HDM | Hypermedia Design Method |
| NAD | Navigation Access Structure Design |
| NAIM | Navigation Access and Interaction Model |
| NCD | Navigation Class Design |
| NCM | Navigation Class Model |
| NP | Navigation Page |
| OCL | Object Constraint Language |
| OMT | Object Modeling Technique |
| OOH | Object-oriented Hypermedia |
| OOHDM | Object-oriented Hypermedia Design Method |
| RA | Requirement Analysis |
| SLEX-Web | Self-pace Learning with Exercising Approach on the Web |
| UID | User Interface Design |
| UIM | User Interface Model |
| UML | Unified Modeling Language |
| UCM | Use Case Model |
| UWE | UML-based Web Engineering |
| WSDM | Website Design Method |

**KAEDAH REKA BENTUK SISTEMATIK BAGI PERMODELAN PROSES-PROSES
KOMPLEKS DAN INTERAKSI DALAM APLIKASI HIPERMEDIA WEB**

ABSTRAK

Sehingga kini, aplikasi hipermedia web telah berkembang daripada sebuah laman web ringkas dan statik kepada sebuah aplikasi laman web yang lebih kompleks, bagi menyokong turutan proses-proses yang kompleks dan interaksi dalam navigasi. Kemunculan pelbagai ciri dalam reka bentuk web dan konsep permodelan seperti permodelan domain konseptual dan struktur navigasi telah membawa kepada isu-isu baru dalam paradigma pendekatan permodelan. Untuk memberi gambaran yang lebih jelas sesuatu paparan struktur reka bentuk domain aplikasi hipermedia web, pereka bentuk web haruslah mengenalpasti dan menentukan dengan jelas secara keseluruhan aspek reka bentuk yang wujud dalam aplikasi yang berkaitan. Oleh itu, objektif tesis ini adalah untuk memaparkan kitaran penuh proses reka bentuk yang terlibat dalam aplikasi hipermedia web berasaskan pendekatan berorientasikan objek dan permodelan UML. Ia akan menyentuh secara mendalam apa yang dipanggil sebagai kaedah reka bentuk aplikasi hipermedia web termasuk ciri-ciri reka bentuknya bagi mempersembahkan kaedah reka bentuk yang mudah difahami dan sistematik, berasaskan UML untuk reka bentuk sesebuah aplikasi hipermedia web yang kompleks. Untuk itu, sebuah kaedah reka bentuk hipermedia yang dipanggil **Com⁺HDM** (*Comprehensive Hypermedia Design Method for Complex Processes Modeling*) dicadangkan selepas melakukan kajian literatur yang teliti terhadap kaedah-kaedah reka bentuk aplikasi

hipermedia web yang ada pada ketika ini seperti OOHDH, WSDM, UWE, ADM dan OOH. Com⁺HDM bertindak sebagai kaedah reka bentuk berasaskan model yang terdiri daripada empat peringkat utama, iaitu analisis keperluan, reka bentuk konseptual, reka bentuk navigasi, dan reka bentuk (paparan) antara muka pengguna, yang dilaksanakan secara proses peningkatan dan pengulangan. Reka bentuk yang dimaksudkan peka kepada tiga aspek; (a) pengenalpastian kelas-kelas maklumat, objek-objek, elemen-elemen, dan hubungan-hubungan yang berkaitan dalam domain aplikasi, (b) menentukan dan memodelkan domain struktur navigasi, seperti kelas-kelas navigasi, kelas-kelas interaksi, dan hiper-rangkaian melalui penggunaan primitif capaian navigasi, dan (c) mempersembahkan interaksi antara pengguna web dan aplikasi melalui reka bentuk abstrak antara muka pengguna (papan cerita). Keaslian Com⁺HDM adalah terletak pada konsep-konsep permodelannya, elemen-elemen permodelan (stereotaip) dan corak-corak untuk pendekatan reka bentuk. Untuk mempersembahkan dengan lebih jelas bagaimana konsep permodelan Com⁺HDM diambil dan disesuaikan dalam paradigma reka bentuk permodelan, tesis ini menyediakan dua contoh kajian kes mengenai aplikasi perpustakaan atas talian dan laman web fakulti (SLEX-Web) bagi tujuan pengajaran dan pembelajaran. Tujuan utama kajian-kajian kes ini adalah untuk menunjukkan faktor-faktor utama tentang bagaimana proses-proses reka bentuk dalam Com⁺HDM berurusan dengan aplikasi-aplikasi kompleks dan proses-proses transaksi, kelas-kelas navigasi dan primitif capaian, dan persembahan interaksi dalam abstrak antara muka pengguna.

A SYSTEMATIC DESIGN METHOD FOR MODELING COMPLEX PROCESSES AND INTERACTIONS IN WEB HYPERMEDIA APPLICATIONS

ABSTRACT

To date, web hypermedia applications have evolved from a simple static information webpage to a more complex web application, supporting sequence of complex processes and navigation interactions. The coexistence of various web design features and modeling concepts in conceptual application domain and navigation structures, have raises new issues on the modeling approach paradigm. To provide a clear structured view on the design of web hypermedia application domain, web designers should identify and clearly define the whole design aspects exist in such applications. Thus, the objective of this thesis is to overview complete lifecycle of design processes involved in web hypermedia application practices based on object-oriented approach and UML modeling paradigm. It will examine deeply into so called web hypermedia design method and its design features to present a comprehensive and yet, a systematic UML-based design method for the design of complex web hypermedia applications. Therefore, a web hypermedia design method called **Com⁺HDM** (Comprehensive Hypermedia Design Method for Complex Processes Modeling) is proposed after having conducted a thorough literature study on existing web hypermedia design methods such as OOHDM, WSDM, UWE, ADM, and OOH. Com⁺HDM acts as a model-based design method consists of four main stages, namely requirement analysis, conceptual design, navigation design, and user interface (presentation) design which are performed in

incremental and iterative process. The designs concern on three aspects; (a) determination of information classes, objects, instances, and associations related in the application domain, (b) capturing and modeling navigation accesses structures domain, such as navigation classes, interaction classes, and hyperlinks through the uses of navigation access primitives, and (c) presenting interaction between web users and application through abstract user interface design (storyboarding). The novelty of Com⁺HDM would base on its modeling concepts, modeling elements (stereotypes), and the patterns of design approach. To clearly present how Com⁺HDM modeling concepts are taken and suits into the design modeling paradigm, this thesis will provide two case studies of an online library application and a web faculty (SLEX-Web) application for teaching and learning purposes. The main concern of these case studies is to show the important factors on how the design processes in Com⁺HDM deal with complex application and transactional processes, navigation classes and access primitives, and presentation of abstract user interface interactions.

LIST OF PUBLICATIONS

This thesis gives an account of the research undertaken solely by the author during the period of July 2006 to June 2009. Some of the materials contained herein have been presented in the following conferences and publications:

- [1] * Azrul, J., Putra, S. and Shahida, S. (2007a) “UML-based Hypermedia Design Method: A Review on Design Processes and Modeling Elements”, Computer Science Postgraduate Colloquium (CSPC07), Universiti Sains Malaysia, Pulau Pinang, 25 & 26 June 2007. See Appendix E.

- [2] Azrul, J., Putra, S. and Shahida, S. (2007b) “Design Processes for Web-Based Hypermedia Engineering”, Proceedings of the 3rd Malaysian Software Engineering Conference (MySec07), Universiti Putra Malaysia, Selangor, pp. 182-186, 3-4 December 2007. See Appendix G.

- [3] Azrul, J., Putra, S. and Shahida, S. (2007c) “Systematic Design Processes of Hypermedia Engineering: A Case Study of SpLEA-Web”, Proceedings of the 1st Regional Conference on Computational Science and Technologies (RCCST07), Universiti Malaysia Sabah, Kota Kinabalu, pp. 154-158, 29-30 November 2007. See Appendix F.

- [4] Azrul, J., Putra, S. and Shahida, S. (2008a) “Conceptual Modeling in Web-based Hypermedia Engineering with Com⁺HDM”, Proceedings of the 4th International Conference on Information Technology and Multimedia (ICIMU08), Universiti Tenaga Nasional, Selangor, 17-19 November 2008. See Appendix H.

* *Best paper award*

- [5] Azrul, J., Putra, S. and Shahida, S. (2008b) “Com⁺HDM: A Model-Based Approach for Complex Web Hypermedia Engineering”, Proceedings of the 4th Malaysian Software Engineering Conference (MySec08), Universiti Malaysia Terengganu, Terengganu, pp. 91-96, 16-17 December 2008. See Appendix I.
- [6] Azrul, J., Putra, S. and Shahida, S. (2008c) “Com⁺HDM: Extending UML Profiles for Modeling Complex Web Hypermedia Applications”, Proceedings of the 2008 International Conference on Advanced Computer Theory and Engineering (ICACTE08), Thailand, pp. 290-294, 20-22 December 2008. See Appendix J.

Besides, this research study also has been awarded with Research Grant (Postgraduate Research Grant Scheme – USM-RU-PRGS) from Research Creativity and Management Office (RCMO), Universiti Sains Malaysia under the topic of “Extending UML Profiles for Modeling Complex Web Hypermedia Applications – A Model-based Approach” – 1001/PKOMP/841002.

CHAPTER 1

INTRODUCTION

1.1 Research Overview

In tandem with Internet Technology, web hypermedia applications and systems have become very popular with explosive growth in its web environments, such as online booking system (airlines booking system), web information application (university's library), e-commerce applications (online banking), web learning (online teaching and learning with performance evaluation), e-courseware for educational hypermedia (learning system via e-book), and information retrieval hypermedia (security application). The integration of various forms of multimedia elements contents on the web such as text, graphics, audio, video, and animation, which presented interactively, makes hypermedia as one of the greatest approaches for expressing ideas in a richer and more natural form. In comparison to basic web information systems (such as tourist information systems) which mainly provide information with minimal aspects of interactive, web hypermedia applications should provide more complex, flexible, and powerful facilities of non-sequential and explorative navigations, higher quality layout presentation of user friendly interfaces, and various forms of information structure contents between web users and the application (Lang and Fitzgerald, 2005).

“Web hypermedia applications are constructed from heterogeneous software components that interact with each other in novel ways... Modeling web hypermedia applications raise new problems and rises to very high challenges due to the coexistence of different interactive styles, application operations, and complex information structures...” (Qian et al., 2007).

According to Lang (2002), a few factors have made web hypermedia application as a complex application, such as (i) they consist of processes flows and interactions, (ii)

implemented as a “*spaghetti*” content structure rather than a simple and straight forward content representation, (iii) using arbitrary linking style with messy navigation that could contribute into a problem called ‘getting lost in hyperspace’, (iv) media controls issues involved with sophisticated multimedia data types – processing, storing, and presenting multimedia data, rather than a simple and static text and numerical data types, and finally (v) larger scope of application concerning on information localization, visualizing knowledge structures, functional operations, and some of managing issues.

Concerning into those aforementioned features, considerable attention has been given by researchers in web hypermedia engineering field to successfully manage the diversity and complexity of this application in order to avoid potential failures that could contribute into a more serious implications (Semia *et al.*, 2006). Therefore, designing and developing web hypermedia applications are not a trivial task; and hence, it has become one of the big challenges for today’s web hypermedia engineering industry. The increasing complexity of web hypermedia applications has raised the need to employ many designing methods and modeling concepts in hypermedia development practices. By looking at recent works on web hypermedia engineering field, there is a strong interest and much enhancement works to be considered on the existing methods for designing web hypermedia applications. The research on this topic is still evolving in order to ensure that all aspects in web hypermedia application practices become more effective and fine-grained, especially in a larger scope and higher complexity applications (Hennicker and Koch, 2001).

1.2 Designs for the Web Hypermedia Applications

Web hypermedia applications are inherently much more complex than basic web information systems (Barna *et al.*, 2003). The evolution in the area of internet technology and web computing in the last few years has made web hypermedia applications increase their diversity and complexity, and hence, they are difficult to design, develop, maintain and being supported in future (Hennicker and Koch, 2000).

Obvious attention has been taken by many researchers in order to capture and deal with these issues and yet, to propose a comprehensive and systematic disciplined method for the design and development practices (Lang, 2005). Each of proposed design methods (which constitute of three major design processes namely conceptual design, navigation design, and user interface design) has its own strength points, covering the whole design and development mechanisms required, supporting process to reuse, dealing with huge information contents and navigation linkages, and able to enhance when application specification and environment changed. Although these proposed methods have strengths, some limitations have been identified in order to tackle some of the design issues (Semia *et al.*, 2005). The following sections will describe in more details those design processes limitations in current existing web hypermedia design methods.

1.3 Problem Overview

The efforts of modeling web hypermedia application in design stage have raises several design issues and increases the challenges on web hypermedia modeling activities. Some of the design issues have been encountered, such as modeling business processes, navigation access structures, activities and transactional workflows, user dependent processes, and so on (Schmid and Rossi, 2004 and Qian *et al.*, 2007). To cope with these issues, several web hypermedia design methods have been proposed such as Object-oriented Hypermedia Design Method – OOHDM (Schwabe and Rossi, 1998 & Schmid and Rossi, 2004), Website Design Method – WSDM (De Troyer and Leune, 1998 & De Troyer and Casteleyn, 2003b), UML-based Web Engineering – UWE (Koch and Kraus, 2002 & Koch *et al.*, 2003), W2000 Framework (Baresi *et al.*, 2001), and Object-oriented Hypermedia – OOH (Gomez and Cachero, 2003 & Koch *et al.*, 2003). However, according to Semia *et al.* (2005) and Koch *et al.* (2004) more design efforts are still required to take place for supporting complex processes, navigation structure and presentational layout. Thus, this thesis will concern on the design practices of web hypermedia applications in the context of integrating complex processes in conceptual domain, interaction and navigation modeling, and user interface presentation between web users and application.

Comparative studies by Semia *et al.* (2005) have shown that most design and modeling methods for web hypermedia application are unable to model complex processes. All reviewed design methods shown that they focus more on organization aspects, navigation and presentation modalities, and user-centered approach. None of them has addressed the complex processes viewpoint. According to De Troyer and Casteleyn (2003b), complex processes can be defined as (a) processes that can be nested (contain set of sub-processes / sub-tasks) (b) processes that can be suspended and resumed again (depends on user demand), and (c) processes that are synchronized throughout their predefined activity sequence. For example, the process of books reservation from online library application can be classified as complex since it involves several sub-processes which needed to perform in sequence actions and at the same time they might relates with several classes which could contribute to the suspension and resuming the processes. This example is inadequately supported by the means of normal navigations mechanisms but they should have to integrate some process flow in order to avoid usability problems and erroneous results from being generated (Schmid and Rossi, 2004). Therefore, this example should be considered in all design stages mainly in conceptual design stage. Application domain must be defined at the first place and then the flow of sub-processes should be captured. All processes (including sub-processes) must then classify as *process class* and treated differently in comparison to the other classes (Azrul *et al.*, 2007b).

In navigation design context, web hypermedia designers should be offered with powerful facilities on modeling interaction processes, their navigation links, and navigation access primitives. Design issues of interactions processes should be highly considered in navigation design stage, in order to provide a clear view on the whole navigation structure, including how interactions occur between users and web hypermedia applications. Therefore, enhancement works should be necessarily conducted in order to get a deeper and a detail view to support those navigation structures and hyperlinks. New navigation classes (for supporting interaction processes) and access primitives (for supporting access structure elements) should be proposed to carry out all navigation objects and instances in the final model.

Most of web hypermedia applications nowadays are highly interactive and web users are constantly required to interact and navigate to the application to fulfill their objectives. All complex processes and navigation objects defined in conceptual and navigation design stages therefore must be considered into the final design stage called user interface design. Most web design methods, such as OOHDM and OOH put less concern on how complex processes and interactions should be mapped into a presentational design. Thus, there is still lacking of modeling concepts on presenting the final result of user interface layout on how many interface elements get involved, where they are located on the page layout, which frame they are belongs to, and what will happen if interaction took place between web users and application.

1.4 Research Motivations

Research area in web hypermedia design is still evolving in many aspects, and yet, there are many design issues to be addressed and integrated (Paloma and Ignacio, 2007). This research is carried out to provide modeling concepts on integrating complex processes and interactions involved in designing web hypermedia applications that is focus on object-oriented modeling approach. The works reported in this thesis will emphasize on the design aspects according to the following problem perspectives – complex processes, interactions modeling, user interface presentations, systematic web hypermedia design method, and UML-based modeling paradigm.

1.4.1 Integrating Complex Processes

As web hypermedia applications begin to infiltrate most of human daily tasks, there arises a need to capture and disseminate of our thinking about how to design and develop a well-structured application that involve complex processes flows. In the recent past, basic web information systems have been designed and dominated by structured methods due to simple and straightforward application contents, but today, many researchers assert and argue that web hypermedia applications should be treated in different way (Schwinger and Koch , 2006 & Seung and Ashraf, 2004).

Complex processes are better treated in an object oriented approach since they comprised of relevant objects and instances which possible to information structure evolution (Baresi *et al.*, 2001). Most of current design methods (OOHDM, UWE, and OOH) employed Object Modeling Technique (OMT) such as Class Diagrams and Activity Diagrams with some little extensions to accommodate processes flows in their design views. With these two separated models constructed (class models and activity models), it is hard for designers and readers to determine which classes belong to the activities defined, and how those activities relate to the classes. Thus, it contributes to the design confusions. For example, one class may consist of several process activities that are related to other classes in acquiring information. There is also a situation where one activity process belongs to several numbers of classes. Therefore, the issues of integrating complex processes in conceptual domain needed to be refined to ensure all classes and processes in both Class Models and Activity Models could be integrated in one specific process view. The design result should able to provide designers with high level conceptual view in application domain, which present classes and their respective processes activities in an intuitive process model views.

1.4.2 Interaction (Navigation) Modeling

Another design issue that motivates this thesis is how to provide effective and efficient navigation structure of the domain model. Baresi *et al.* (2001) has stressed that web hypermedia design method should able to model navigation structure and hyperlinks in order to present how navigation nodes are reached by users. In the context of complex processes (which might known as complex interaction in navigation perspective), users are not only clicking items, navigating, and read information on the web, but they also have the capability to trigger and execute functional operations (processes) and transactions, through real time interactions. Thus, how these interactions should take place in navigation design model? For example, navigation classes resided in navigation model represent navigation nodes (targets) that are reachable by users, but how they (navigation classes) should provide information about interaction processes that are underlies within the nodes? According to Koch *et al.* (2004), there are only a few design

methods concern on accommodating interaction processes into navigation aspects (from the process concerns) such as OOHD, UWE, and OOH. Most of efforts employ Activity Diagrams to support the interaction views. However, there is still lacking of modeling facilities to preview how interaction processes should be located in navigation design model clearly. Therefore, this thesis will refine some ideas to present how those interaction processes can be located in a navigation model using several additional modeling facilities.

Secondly, navigation usability issues have been highlighted in Tirapat and Achalakul (2006). Some of major problems in navigation design relate with users who fail to find required information and sometimes they are getting lost in navigation hyperspace. They also might require extra searching time before they can find required information. These are all due to poor hyperlinks determination and messy navigation structure with lacking of navigation access elements provided in current web hypermedia design methods such as OOHD and UWE. For example, they only provide basic navigation access elements such as index, guided tours, query, and menu. These four elements are not enough to specify complex navigation access structures of web hypermedia applications (Azrul *et al.*, 2007c). Therefore, this thesis concerns on providing more alternatives navigation access elements to ensure navigation model equipped with suitable and best appropriate access elements. The proposed access elements should be able to overcome limitations resided in current navigation access elements and therefore assisting web users to find information in navigation hyperspace using lesser time.

1.4.3 User Interface Presentation

Design issue in user interface presentation of web hypermedia application relates to the locality of navigational objects and its instances on the page layout. This final design process requires designers to transform all objects and instances in navigation model to user interface elements. Presentation layout should describe logical presentation of each user interface elements (such as position and quantity), not the physical aspects (font type, size, color, etc). Since user interface design efforts relates to art skills and

creativity aspects of designers, many web hypermedia design methods are not totally concerns on this design process. Much of the works are left over to implementation stage and let developers decide the look and feel of the page layouts. However, in the case of UWE, Koch and Kraus (2002) provide ideas on how to construct static and dynamic presentational layouts to build user interface model. The static model view should capable to illustrate how page layout of web hypermedia application is drafted, while dynamic model view employs Sequence Diagrams to present behavior aspects of users in performing actions in particular page layout. The modeling efforts proposed by UWE however a bit complex and hard to understand in terms of choosing and providing user interface elements in the final model. The modeling guidelines given in UWE should be refined as to provide a better understanding on how user interface elements can be transformed directly from navigation objects and instances.

1.4.4 Systematic Web Hypermedia Design Method

Despite of their rapid growth in its web environments, web hypermedia design and development practices have generally been ad-hoc and trial-and-error, leading to poor quality of the final product (Semia *et al.*, 2006, Avgeriou and Retalis, 2005 & Uden, 2002). According to Avgeriou and Retalis, (2005), methods and tools currently existed for web hypermedia design are very few and of dubious standards. Thus, many applications designed and developed are lack of rigor without a systematic approach (Murugesan *et al.*, 1999). By considering the facts given, design processes used in basic web information systems are therefore, not well-suited or even inadequate to the web hypermedia applications practices, especially for designing large-scale applications with complex operations and functionality. More design supports must be given on their information contents and structures, navigation hyperspace structures, and presentation layout. Thus, there is a necessity to provide web hypermedia design method which could perform in systematic way (within sufficient modeling facilities and guidelines), comprehensive (easy to use with understandable design features), and flexible (to reuse in various type of web hypermedia application).

1.4.5 Necessity of UML-based Modeling Paradigm

To provide a comprehensive web hypermedia design method is to provide easy-to-use design features in the modeling paradigms. Many web hypermedia practitioners are lacking of knowledge and poorly understood the concepts of design and development practices, and yet, hardly to identify which design method is of effectively to be carried out of the design and development activities (Lang and Fitzgerald, 2005). As a result, most of the web hypermedia applications are not being designed and developed according to the appropriate methods and tools, thus, contributing to the application failures. Obviously, most of web hypermedia practitioners are having little understanding and not concerning on how web hypermedia applications should be designed and developed in a right way according to design methods. In short, they do not know how to differentiate design methods for their effectiveness in the design and development practices. And still, no consensus among them for describing which method to be the best used for the practice (Semia *et al.*, 2005). To overcome this limitation, a well-known modeling paradigm, called Unified Modeling Language (UML) perhaps could provide a better understanding in modeling efforts (Alhir, 2001). It has been widely used in modeling practices and compatible in most software and web hypermedia applications. UML presents several standard notations throughout their definitions and allow designers to use specific features of UML Profiles, called stereotypes which hold unique definitions, notations, and descriptions compared to the standard one. UML stereotypes are specific modeling elements within descriptive and restrictive information on each and defined according to particular web hypermedia design method. The uses of UML stereotypes within its profiles make the modeling efforts on web hypermedia applications become much easier, expressive, and effective throughout its standard and comprehensive design features. Thus, this thesis believe the uses of UML modeling paradigms seems to be a right choice in giving a better understanding, flexible, and appropriate modeling features to model particular web hypermedia applications.

1.5 Research Aims and Objectives

The key to success in web hypermedia design practices is the ability to capture needs from users, translate and model them into a so called design models, and interpret all the design contents systematically. Generally, the aim of this thesis is to provide a clear and detail views on web hypermedia design practices, which could assist both designer and developer to reap the rewards of utilizing web hypermedia design aspects to its full capacity. This thesis has been identified to investigate and propose a web hypermedia design method to design complex web hypermedia applications with a focus on object-oriented approach, specifically on UML modeling paradigm. The main objectives of this thesis are:

- (i) To propose and provide a comprehensive, systematic, and flexible content of web-based hypermedia design method, which could serve as a foundation of capturing user requirements and designing the whole processes of web hypermedia applications. This should outline three major design processes, called conceptual design, navigation design, and user interface design that interrelate each other to create a web hypermedia design environment, which impacts upon the success or failure of the web hypermedia design practices.
- (ii) To propose complex processes modeling under conceptual design stage in order to capture flow of complex processes in application domain and integrate them (conceptual classes and processes activities) in one specific process model. Several new UML stereotypes should be defined to support the modeling efforts.
- (iii) To integrate interaction processes in navigation model throughout navigation classes, hyperlinks, and access structures in navigation design stage. Several new UML stereotypes should be defined to react as the navigation objects and instances.

- (iv) To provide mapping rules between navigation design and user interface design stages. The aim is to present presentational page layout on how navigation objects and instances defined in navigation model are mapped as user interface elements.
- (v) To develop and implement an example of real project (case study) of web hypermedia application. The case study should imply all design activities and modeling concepts proposed in (ii), (iii), and (iv). Qualitative evaluation approach and analysis is undertaken to validate all proposed UML stereotypes.

1.6 Research Contributions

Towards the end of this thesis, a web hypermedia design method called Com⁺HDM is proposed. Com⁺HDM is an object-oriented modeling approach, and employs three important design directions, namely conceptual design, navigation design, and user interface design to practically used in complex web hypermedia design practices. It models user-intensive web hypermedia application that comprises of complex functional operations (processes) and sophisticated linkages of navigation and interaction classes. First and fore most, functional requirements from users is captured and elaborated in order to define and classified features that characterize the web hypermedia application. Then, three other models for each of design stages are modeled and constructed by means of (a) clarification of classes, objects, and associations to capture application domain specification, (b) definition of navigation structures which supports the specification of the conceptual contents by defining a number of navigation classes, interaction classes, hyperlinks and access structures, and (c) presentation layout to present user interface elements as provided on screen in the real web hypermedia application.

The main characteristics of Com⁺HDM are:

- (i) It is an object-oriented, iterative, and incremental process based on Unified Process. Main focuses are on user requirements analysis and three design processes (conceptual, navigation, and user interface). Some other issues such as maintenance, project management, testing, and quality management are goes beyond of this study.
- (ii) It is a modeling (design) approach where models are constructed as results of each design stage. Com⁺HDM should able to design and construct use cases model, conceptual models, navigation models, and user interface models.
- (iii) It supports systematic modeling and graphical visualization of models. Models are visually represented in UML graphical notations based on the general extension mechanisms in UML Profiles. Several UML stereotypes are defined in each of design stages to provide designers with specific and expressive modeling elements. They hold their own definition, descriptions, and notations.
- (iv) It specialize design directions by extending the coverage of current web hypermedia design methods. The issues and limitations of complex processes, interactions, navigation structures, and user interface elements are deeply focused.

In general, Com⁺HDM concerns on modular design, which means that models are constructed for every design stages that separated into different level of abstractness, and thus it will allows web hypermedia practitioners to concentrate their efforts on different concerns one at a time. The evaluation of each modular result (for every single model constructed) is done through qualitative case studies of an online library application and a faculty web application as described in Chapter 4 and Chapter 5, and Chapter 6, respectively. The details of evaluation strategy will be covered in Chapter 3.

1.7 Thesis Outline

This thesis is organized in seven chapters. Figure 1-1 illustrates how this thesis organizes research aims and objectives (contributions) into corresponding chapters.

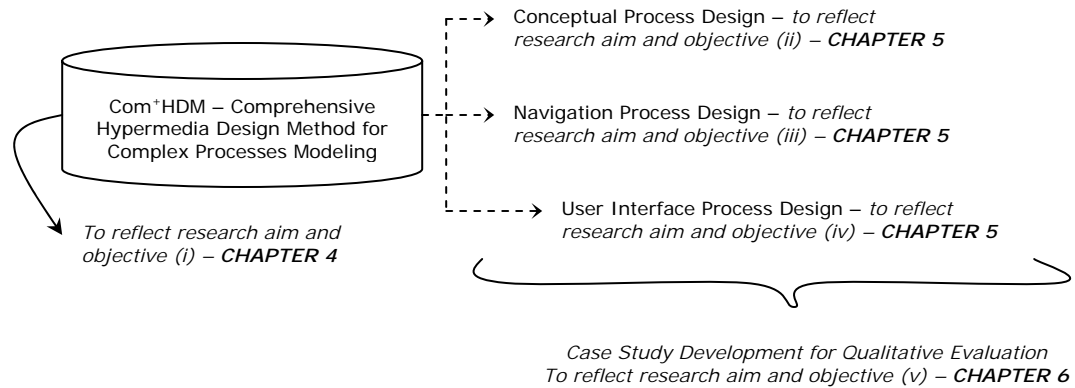


Figure 1-1: Research Works on Corresponding Chapters.

Each of thesis chapters is detail as the following:

Chapter 1: Introduction. This chapter provides background context of the research by elaborating why web hypermedia design is chosen as the topic of research study. The reasons are then strengthened by a number of problem views and research motivations. All research questions are then discussed and followed by the aims and objectives of this research. Research contributions are described to present some basic idea on what is being scoped and focused for this study. Finally, a roadmap of the whole thesis is highlighted and described at the end of the chapter.

Chapter 2: Literature Review. This chapter provides an overview and highlights the discipline of systematic design and development of web hypermedia applications. In addition, it also provides comparison of current existing hypermedia design methods. A number of design aspects are discussed to present how each of reviewed method reflect to the real design practices of hypermedia application including their primitives and notations. The issues on complex processes modeling and navigations structures are also clearly elaborated in conjunction to each of the reviewed design method.

Chapter 3: Research Methodology, Design, and Issues. The idea of this chapter is to present the research procedure (design) and approach taken to the conduct of qualitative case study and feature analysis evaluation.

Chapter 4: A Comprehensive Hypermedia Design Method for Complex Process Modeling – Com⁺HDM. This chapter presents and discusses theoretical background of proposed web hypermedia design method for modeling complex processes and interactions in web hypermedia applications. Topic of requirement analysis for capturing functional requirements are also included, which covers activities that are critical for the success of web hypermedia applications.

Chapter 5: Modeling Techniques for the Design of Complex Web Hypermedia Application. This chapter thoroughly presents the major contributions of this thesis which show how current problems and limitations stated in Chapter 1 are being treated and solved. Conceptual design stresses the description on modeling information structures and contents of application domain. Navigation design focuses how to specify and model the navigability through the content of web hypermedia applications. Finally, user interface design concerns on presentation layout modeling to ensure that interactions between web users and application is simple and self-explanatory.

Chapter 6: Design and Development of SLEX-Web Application – A Case Study. This chapter describes how modeling concepts and design processes in Com⁺HDM are evaluated and validated through a case study.

Chapter 7: Conclusions. The results of this research work are concluded. Besides, some ideas on refinement works in the future for this research field are also being provided.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In general, this chapter will focus on the scope of research area – design processes in web hypermedia application. At the beginning, this chapter describes general terms of research area and scopes including background of web hypermedia engineering, web hypermedia applications, and design processes of particular application domain. Then, several numbers of existing web hypermedia design methods are discussed in order to compare their modeling concepts and design features. Design issues of complex processes and interaction modeling are highlighted according to reviewed design methods. Finally, findings of the studies are concluded at the end of the chapter.

According to online *Wikipedia* encyclopedia, web application can be defined as an application that is accessed through web browser over a vast internet network such as Internet Explorer or Mozilla Firefox. Besides, it can also defined as any computer software application built in browser-supported language in a specific web-based controlled environment for web users in order to achieve particular objectives. Common web applications examples are such as web mail application (*gmail* or *yahoo mail*) and geographic information system (*google map*). On the other hand, web hypermedia application brings a similar definition to web application where the word *hypermedia* gives more consideration on any application that could be navigated via navigation links or *hyperlinks* in which multimedia elements are intertwine to create a general form of non-linear medium of information delivery system. Examples of web hypermedia application include web portal (*university's website*), online ticketing system (*booking system*), and e-learning application. Web information system is another terminology that brings a same portion of definition to both web application and web hypermedia application. Generally, web information system can be defined as an application that

provides web users or other web applications with data, information, and services. A web information system usually consists of one or more web applications. *Google* and *Facebook* applications are the best examples to present web information systems.

After more than a decade, it is obvious to say that the design and development practices of web hypermedia applications are not possible to face critical, complex and large scale web requirements without conforming a proper way of development lifecycle. In general, it is not a one-shot development practices but it is rather complete processes performed throughout the whole lifecycle of a web hypermedia application, similar to software engineering lifecycle practices on software design and development. Considering to the large number of publications, workshops, and conferences, *web hypermedia engineering* can be considered as part of the *software engineering* definition (Kappel *et al.*, 2005).

“Web hypermedia engineering is a systematic, disciplined, quantifiable approach to the planning, development, operation and maintenance of web hypermedia applications. The development consists of a set of well-defined sub-processes with measurable outcomes ...” (Uden, 2002)

According to Uden (2002), web hypermedia engineering can be defined as a systematic, disciplined, and quantifiable approach to deal with all aspects of life cycle in web hypermedia production. The lifecycle consists of well-defined processes and their subs with measurable outcomes, starting from conception and planning, design and modeling, development to implementation, performance evaluation, and continual maintenance (Ginige and Murugesan, 2001). Each of them is a continuous and iterative activity in order to support the changes made in application requirements, contents, and functionality, during the completion of the whole lifecycle. On the other hand, Kappel *et al.* (2006) defines *web hypermedia engineering* in other specific way as an application of systematic and quantifiable approaches with concepts, methods, techniques, and tools to cost-effective requirement analysis, design, implementation, testing, operation, and maintenance of high quality web hypermedia applications.

The subject of web hypermedia engineering has become ubiquitous in everyday life, surpassing all other technological developments in terms of supporting the global communication medium for delivering information and services. For the past decades, web hypermedia applications have experienced a vast evolution in its reason of existence. These applications are full-fledged, complex software which offer interactive systems, customizable services, data intensive and transactional database (Kappel *et al.*, 2002). Thus, the web hypermedia engineering has become one of the important research fields among their practitioners for ensuring these applications are successfully implemented in the several specific areas of World Wide Web.

There is also a need of design and development infrastructures in the lifecycle as described by Ginige and Murugesan (2001), to gain the capability of supporting the application evolution in a controlled environment, but flexible and consistent to keep information current and meet user needs. These infrastructures however, are contrary to the one that used and applied in software engineering manner since web hypermedia engineering incorporates with new approaches, methodologies, techniques, and guidelines which poses many additional challenges. All of these are represent as a kind of proactive development practice in order to complete a success web hypermedia application, and these have encourage practitioners to adopt web hypermedia engineering principles. For the sake of clarity, this thesis will use the terms *web hypermedia engineering* and *web hypermedia application* for the rest of the thesis contents since both hypermedia engineering and hypermedia application, brings the same definition to describe the whole practices applied for developing web-based applications that are used by people to access and disseminate information and services.

2.2 Web Hypermedia Design

Within a short period, web hypermedia applications have become ubiquitous in our daily routines, especially for seeking information (such as organizational web portal and web information services) and managing organizational tasks (such as web e-learning and online banking application). An enormous number of applications have been used in various areas and their widespread acceptance points to the effectiveness of web design approaches (Semia *et al.*, 2005). Each web hypermedia application may have to fulfill a number of roles, ranging from information delivery to interactive service and transaction, depending on its type and delivery approach. The functional requirements of this application, the number of concerned user groups, and the pace at which applications must be developed, making the design of web hypermedia application a challenging endeavor (Distante *et al.*, 2007). Besides, the process of designing hypermedia applications also demands the abilities from designers to analyze application domain, to manage multimedia elements, to define adequate structuring models in both conceptual and hyperlink levels, to manipulate web hypermedia design processes (conceptual, navigational, and user interface – see Figure 2-1), and to choose appropriate implementation and maintenance techniques. All of these efforts playing an important role as it may become the most critical factors and the turning points to produce a good quality and effective web hypermedia applications. Among of all these efforts, this thesis will concentrate into so called, *web hypermedia design processes* within its main design directions and modeling concepts.

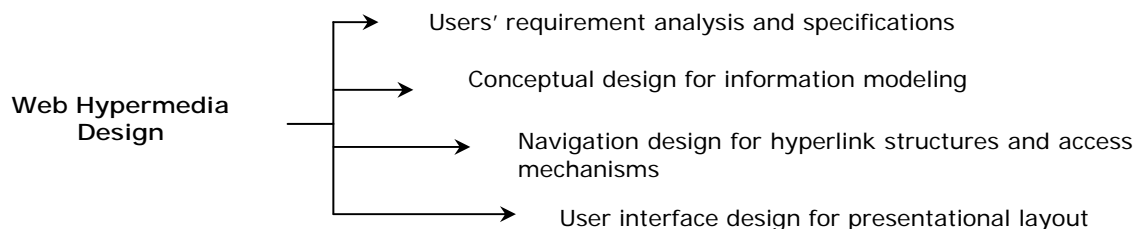


Figure 2-1: Design Processes for Web Hypermedia Applications.

In overall aspects, it has become mandatory to provide for user's needs, expectations, and preferences for different information perspectives, interaction styles, and user interface layout, by considering web hypermedia designs as illustrated in Figure 2-1.

2.2.1 The Need for Systematic Design

The process of designing and developing web hypermedia applications is one of the big challenges for today's web hypermedia engineering industry. In comparison to information system design, web hypermedia application demands a number of additional design aspects such as complex application structure and information contents, various interactive operations and functions, messy navigation hyperlinks and access structures, and web presentation layout. According to Lang and Fitzgerald (2005), web hypermedia applications should support a variety presentation of information perspectives, more complex navigation structure and access primitives, and high quality of user interfaces interactions. However, current web hypermedia applications often fail in their design and functionalities, lack of qualities and struggling to meet user requirements (Avgeriou and Retalis, 2005). One of the reasons is web hypermedia applications are getting complex on its scope (Barna *et al.*, 2003 & Barry and Lang, 2003) mainly for the complex processes and functional requirements (Distante *et al.*, 2007). Besides, many web hypermedia designers, developers, and practitioners are lacking of knowledge and poorly understand the concepts of the design and development practices, contributing to the applications failure (Lang, 2001). In addition, choosing an appropriate and best suitable design method is another challenge among designers and thus, development practice has generally been ad hoc basis (Uden, 2002), leading to inconsistent design, poor quality results and hardly to accomplish user specifications. On ad hoc approach, designers and developers place too much emphasis on the product interface, not to the content, purpose, functionality, and far from behind to consider the user's capabilities and profiles. Most of them delve directly into the development and implementation phases paying minimal attention to requirements acquisition and specification and going through a very informal and more to *trial-and-error* design processes. The findings made by Lang and Barry (2001) have revealed that web hypermedia practitioners are not

accustomed to apply and use any of the web hypermedia development methodologies. Thus, there is a need and demand for systematic, well-structured, and comprehensive design method, in order to bring the chaotic process under control.

2.2.2 User-centered Design Approach

As a main medium of transferring and manipulating information to the users, hypermedia application must exploit its facilities for a variety of purposes in order to provide users with exploratory access to information content based on semantic relationships and navigations between information elements (Giachetti, 2005). As more people are getting common with web hypermedia application, it must be admitted and necessary to provide users with accurate information, services, and their expectations and preferences for different navigation and interaction styles and modalities. Thus, designing web hypermedia application by focusing all the needs required by users is called, *user-centered* design approach. This approach gives consideration to the fact that users of this application are composed of different kinds and characters, which can be grouped into a number of user classes, as described in De Troyer and Leune (1998). Different classes of users may have different requirements, either information requirement or navigation requirement. Information requirement tells designer what information, including information structure, data transactions, functional requirement and usability requirements should be there for users (De Troyer, 2001). Each of user classes defined has its own information requirements and that should need to be reflected in the content of the application. However, not all information requirements are relevant for all users. Some users might demand precise and details information in broader presentation while some only seek brief and common information, in a simpler presentation.

In comparison to information requirements, users are also required to describe their navigation preferences in order to present how information is navigated between the information structures. In Baresi *et al.* (2001), navigational requirement analysis is conducted to describe basis information within its navigation structures (hyperlinks) needed by different users of the applications. Hyperlinks are part of exploratory mechanisms in web hypermedia applications that enable direct and non-direct accesses to information by transferring users from origin page to destination pages, depending on which navigation access elements user selected. Defining well-structured hyperlinks therefore, could solve one of the most problematic issues in usability problems, called *lost-in-hyperspace syndrome*. This syndrome indicates that if the information and navigation processes are not well determined or defined, users may easily get lost in navigation hyperspace for not being able to find information they are looking for. In some cases, they needed to spend too much time to find information in the hyperspace. Some other problems have been stated in Tirapat and Achalakul (2006), where web users might also facing navigation errors while searching or manipulating transaction in the application processes. These situations show that without appropriate efforts on the design of users' requirements, the outcomes of application might becomes more difficult to explore, confusing, and time consuming for those users who try to search or manipulate the desired information in the application domain.

As a conclusion, user-centered design is a very important and effective approach as it leads web hypermedia application to provide a better tailored understanding to user needs and expectations, both in information representation and navigation preferences. The end product therefore, may have a higher usability and great user satisfactions. In next section, this thesis will describe major processes involved in analyzing and designing web hypermedia applications.

2.3 Web Hypermedia Design Processes

This section describes in details four major processes involved in analyzing and designing web hypermedia applications. It gives overview on the importance of analysis and design processes, and followed by sub-sections that explain modeling efforts in each of process activities. In general, requirement analysis stage begins the modeling efforts that concerns on capturing users' needs based own their specifications. During the design phase, the specifications are converted into design models to support those requirement specifications. Generally, there are two design orientations, namely *structured design process* and *object-oriented design process*. Structured design process mainly focuses on constructing design specification towards the use of entity-relation diagram (E-R Diagram). Information objects and elements are defined as entities of application domain that has relations to each other. Relationship Management Methodology (RMM) (Isakowitz *et al.*, 1995) and Hypermedia Design Method (HDM) (Garzotto *et al.*, 1993) are two examples of well-known design methods that apply E-R Diagram as the background of its modeling concepts. On the other hand, object-oriented design process has a tremendous growth in the late 90's. In comparison to the structured design process, object-oriented design constructs a so called, Class Diagram in order to present classes, objects, instances, and associations that are made up into the application domain. UML-based Web Engineering (UWE) (Koch *et al.*, 2001), Object-oriented Hypermedia Design Method (OOHDM) (Schwabe and Rossi, 1998), Web Site Design Method (WSDM) (De Troyer, 1998), and Object-oriented Hypermedia (OOH) (Gomez and Cachero, 2003) are some of well-established methods applying this design orientation in their design practices.

This thesis will provide in-depth elaboration on object-oriented design process. Ongoing research efforts have found that most of object-oriented-based design methods mainly used for web hypermedia application development are model driven and consist of a number of design processes, namely *conceptual design*, *navigation design*, and *user interface design* (Barna *et al.*, 2003). Figure 2-2 shows the research scope in this thesis according to the web hypermedia engineering lifecycles.

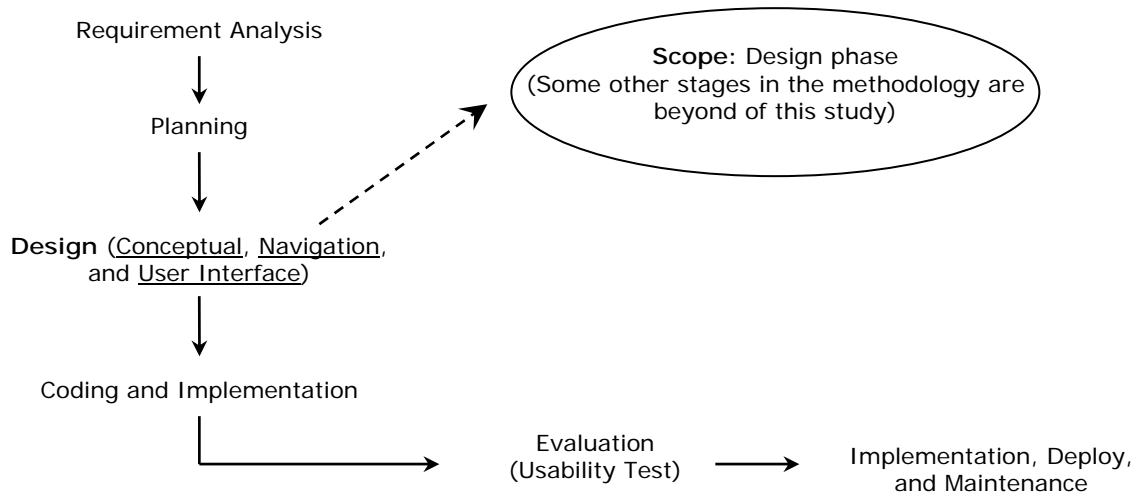


Figure 2-2: Scope of Design Processes in Web Hypermedia Engineering.

The efforts of these design processes are normally being done in iterative and incremental approach. Generally, all design processes are treated as separate activities to allow designers to concentrate on different concerns one at a time. In addition, modular and reusable designs also can easily be obtained. For each of them, a model is developed to present the result of the design efforts and they are validated according to guidelines for web hypermedia design improvements until they reach a desirable level. Figure 2-3 illustrates the details of design processes (conceptual design, navigation design, and user interface design) of a web hypermedia application. Some methods are using their own created notation, while the others are conforming existing standard notation such as Unified Modeling Language (UML) (Booch *et al.*, 1998).

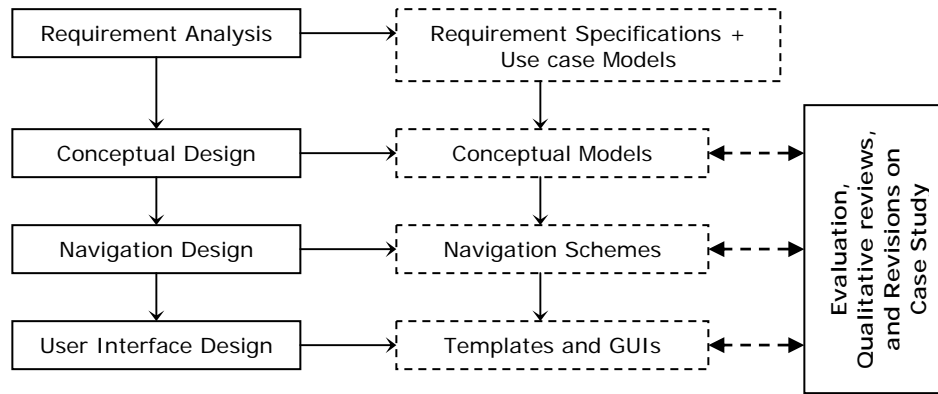


Figure 2-3: Details of the Design Processes in Web Hypermedia Applications.
(Avgeriou and Retalis, 2005).

The following subsections will briefly provide overviews on each of processes activities involved in web hypermedia design practices.

2.3.1 Requirement Analysis and Specifications

Even though requirement analysis is far apart from design process, most of web hypermedia design methods based on user-centered approach include it as a mechanism for incorporating functionality into the web hypermedia applications (Giachetti, 2005). This is because requirement analysis is mainly conducted to gather and analyze information needs from users, indicating how users will behave and react to the application while they using it. Generally, there are two classes of requirements, namely *functional requirement* and *non-functional requirements* (Escalona and Koch, 2004). Functional requirement includes specific information on what an application will do accordingly to user satisfactions that describes a function that an application must be capable of performing in order to solve a problem. These are really related to the behavior of the application. For example, functional requirements are typically phrased with subject/predicate, constructions, or noun/verb such as “the application should provide quiz session and result is generated and saved in database once the student completed the quiz session”.