# Modeling Complex Processes, Navigations, and User Interface in Web Applications

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*Abstract*—**In comparison to basic web information which mainly provides static information within minimal interaction aspects, there is a need for web application to contain more complex and specific information throughout its domain structure. Web application has significant information compositions such as its domain processes, users' interaction, content structures, dynamic navigation links, and user interface presentation. Thus, designing and modeling web application requires extra attention and meticulous efforts. In this paper, we present Com$^+$HDM (Comprehensive Hypermedia Design Method for Complex Process Modeling), a comprehensive and systematic web design method to support all aforementioned characteristics in the context of web application design practices. Com$^+$HDM has been shown particularly useful in modeling flow of complex processes involving complex interaction between web users and the application. Specific modeling elements are provided to facilitate designers in organizing and integrating specific information at high level views to produce expressive design models on the domain structure. We will describe in details on how Com$^+$HDM can be used to design a specific web application example, throughout the processes requirements and design models, in order to highlight the internal design strengths of this approach.**

***Keywords- web application, web design processes, complex process modeling, navigation structures, user interfaces.***

## I. INTRODUCTION

In tandem with internet technology, web applications have become very popular with explosive growth in its web environments, such as interactive web portal (web airlines system), web information application (university's library), e-commerce applications (online banking), web learning management system (online teaching and learning with performance evaluation), e-courseware for educational hypermedia (learning system via e-book), and information retrieval hypermedia (web 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 web application 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 applications should provides more complex, flexible, and powerful facilities of non-sequential and explorative navigations, higher quality layout presentation of user friendly interfaces, and varied forms of information structure contents between web users and the application [1]. Thus, the effort of designing and developing these applications have raises a number of design issues on web modeling activities [2]. 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 [3,4]. To cope with these issues, several web design methods with different design features and modeling concepts have been proposed such as Object-oriented Hypermedia Design Method [8], Website Design Method [9], UML-based Web Engineering [5,6], and Object Oriented Hypermedia [10]. However, more design efforts are definitely required for supporting a various way of dealing with complex process and domain structures of web applications, perhaps in a more comprehensive and systematic design aspects. Concerning into those aforementioned features, considerable attention has been given to successfully manage the diversity and complexity of this application in order to avoid potential failures that could contribute into a more serious implications [3]. Therefore, designing and developing web applications are not a trivial task; and hence, it has become one of the big challenges for today's web engineering industry. By looking at recent works, there is a strong interest and much enhancement works to be considered on the existing methods for designing those applications. The research on this topic is still evolving to ensure that all aspects in web application practices become more effective and fine-grained, especially in a larger scope and higher complexity applications [12]. This paper is organized as follows. In Section 2, we describe the principles of web design processes including two issues that need to be highlighted – complex processes and interactions. Section 3 will describe the proposed web design approach called Com$^+$HDM (Comprehensive Hypermedia Design Method for Complex Processes Modeling). We will provide information about the background and profiles including the modeling elements used in particular design stages. In Section 4, we demonstrate and discuss the design efforts taken to model a web example. These will cover three major design stages called conceptual design, navigation design, and user interface design. Section 5 will summarize and discuss the overall works of Com$^+$HDM. Finally, we conclude our works in Section 6.

## II. THE WEB DESIGN PROCESSES

Web hypermedia design methods have been proposed in the past few years to tackle and support the design and development of web applications. Ongoing researches have found that most of the methods are model driven and consist of a number of design processes [4,14]. The effort of these design processes are normally being done in iterative and incremental approach. For each design process, models are constructed to present the application design. 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 models, while the others conform to existing notations such as Unified Modeling Language (UML) [16].

Generally, web design practices involve with three design stages - conceptual design, navigation design, and user interface design [4,17]. In conceptual design process, designer concentrates on conceptual *"what"* and *"how"* to describe information structures in application domain model [6]. It should provide classes, objects, attributes, and associations between the users and the application. The flow of complex processes also should be highly concerned in this design stage. The outcome of conceptual design process is presented through conceptual model. It should present and determine which information is made available, including the details. Upon the completion of conceptual design models, navigation scheme are designed and constructed as navigation models. The main objective of navigation design process is to specify how information in conceptual design models is presented as navigation classes and inter-connected with hyperlinks. Web 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 design processes can be performed in two different sub-design efforts, called navigation class scheme and navigation context scheme [4]. In the former, navigation classes are defined according to the constructed conceptual model through its conceptual classes. It represents navigation nodes that are reachable by web users. These nodes are linked appropriately depending on the user navigation preferences. On the other hand, navigation context scheme is aimed to equip those navigation nodes with access elements. This would define *"how"* those navigation nodes are reached by web users. The final design process is user interface design. User interface model is constructed to present abstract user interface design – presented through logical views of web page layout, incorporating the visual characteristics of information being presented on each navigation node. Page components or user interface elements should be defined through graphical notations (icon) before designers can deploy them as user interface objects on particular page layouts [18]. The idea is to locate page components on page layout according to the storyboard. At the end of the process, user interface models are constructed to present screen layout including their page components and its position.

### *A. Complex Processes and Interaction Designs*

Conceptual design is mainly focus on the domain structure of particular application design. It should provide information structure including flow of processes that reside in any related classes. The issues of dealing with complex processes in conceptual domain should be refined to ensure all classes and its contents could be integrated with the existence of the complex processes. The design approach should provide designers with high level conceptual view in application domain, which present classes and their respective processes activities in an intuitive process model views. According to [9] and [15], complex processes can be defined as (i) processes that can be nested or contain set of sub-processes (ii) processes that can be suspended and resumed again, and (iii) processes that are synchronized throughout their predefined activity sequence. Complex processes should be treated in object oriented approach since they comprised of relevant objects and instances which possible to information structure evolution. Most of current hypermedia design methods such as OOHDM, UWE, and OOH applied Object Modeling Technique (OMT) with some little extensions to accommodate processes flows in their design views. However, it is hard to determine which classes belong to the processes defined, and how those processes flows relates to the classes. For example, one class may consist of several process activities that relate to other classes. In contrast, one activity process can also belongs to several numbers of classes. Therefore, the issues of integrating complex processes should be refined to ensure all classes and processes could be integrated in one specific process view.

Another design issue that motivates us is how to provide effective and efficient navigation structure of the domain model. Web hypermedia design method should able to model navigation structure in order to present how navigation nodes could be reached effectively by the users [19]. 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 and transactions. Thus, how these interactions should take place in navigation design model? According to [7], there are only few design methods concern on accommodating interaction processes into navigation aspects such as OOHDM, UWE, and OOH. Most of efforts employ UML Activity Diagrams to support interaction views and there is still lacking of modeling facilities to present how interaction processes should be placed in navigation design model [3]. Besides, navigation usability issues have been highlighted in [19]. Some of major navigation usability problems have been discussed such as (i) users failed to find required information; (ii) users are getting lost in navigation hyperspace and; (iii) users might require extra time to find required information. These are all due to poor hyperlinks determination and messy navigation structure with lacking of access elements provided in current design methods. Therefore, we concerns on providing more alternatives design features to ensure navigation model equipped with suitable and best appropriate navigation access elements.

## III. COM+HDM: OUR APPROACH

This section will describe a comprehensive, systematic, and flexible design method for web application design practices. It would incorporate comprehensive and systematic dimensions of three design stages called conceptual design, navigation design, and user interface design. In general, there are three main objectives of Com+HDM; (i) to model complex processes through its systematic conceptual design and information modeling; (ii) to provide navigation links and access structure mechanisms to support process flows and their interactions; and (iii) to present interaction between web users and web application through abstract user interface layout. These objectives should be reflected on each of design stages, respectively. Com+HDM can be applied in increment and iterative design fashion to support reusability design principle, leading to a systematic and flexible development lifecycles for implementing web applications. Com+HDM is a generic object-oriented modeling method based on Unified Modeling Language (UML) modeling paradigm [16]. It is a model-based approach where models are built in separated design stages to provide better modular results. Com+HDM is a design method that compares and combines well proved design aspects among existing design methods to tackle and overcome some of major challenges specifically in complex processes and interaction modeling. Therefore, Com+HDM should improve the resulting combinations with some new ideas of modeling concepts and design features through its methodological approach. Figure 1 presents several design processes in Com+HDM to produce models such as Use Case Models, Conceptual Model, Navigation Models, and User Interface Models.

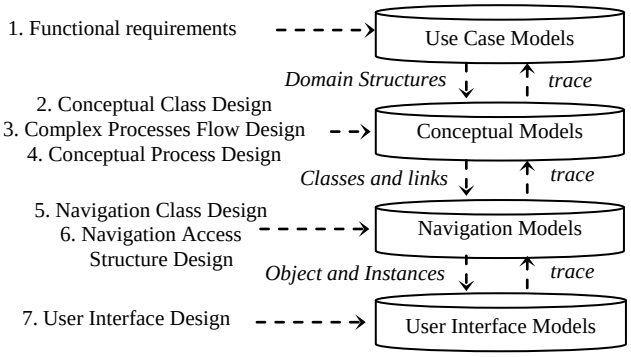


Figure 1. Methodological Approach of Com+HDM.

Design models should complement each other to provide specific design inputs and information specifications. Treating them in different stages allow 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. Models are traced to provide new design primitives for successive models.

### A. The Design Stages and Modeling Elements

Com+HDM provide details specifications on web application through its internal design perspective. For each design stage, Com+HDM equipped with powerful modeling elements to construct design models. This will include standard UML modeling elements and specific modeling elements (stereotypes) which have their own specific definitions of modeling features. According to Figure 1, Com+HDM uses standard UML modeling elements to develop Use Case Models and Conceptual Models (UML Class Diagram and UML Activity Diagram). However, Conceptual Process Models, Navigation Models and User Interface Models are constructed using UML stereotypes. Table 1 (see Appendix) shows UML stereotypes for constructing Conceptual Process Model (CPM).

During Conceptual Process Design stage, all stereotypes complement each other in order to construct CPM. This effort differs from other existing design methods in a way to construct separate and detail process class features which integrate complex processes flows in one process design view. Upon completing CPM, designers should consider another set of UML Stereotypes for designing Navigation Class Model (NCM). Table 2 (see Appendix) describes the stereotypes in Navigation Class Design (NCD).

NCM should present navigation and interaction classes reachable through hyperlinks. It describes what information and hyperlinks offered in navigation hyperspace. However, the model is not yet completed without navigation access structures. The idea is how to provide navigation mechanisms to access information on the web. Table 3 (see Appendix) provides UML Stereotypes (access structure) offered in Navigation Access Structure Design (NAD). The design model is presented through Navigation Access and Interaction Model (NAIM). Modeling efforts can be divided into two separate parts; providing menu access element, and providing access structures. For both parts, designers have to play vital role in choosing the best appropriate and most suitable access structures in the navigation hyperspace. It should provide appropriate selection of access structures to ensure users able to achieve their navigational objectives and information needs.

The final design stage is User Interface Design (UID). The main objective is to provide graphical guidance of presentation model that present user interface (UI) elements of every single web page. The concern is on the design of logical structural organization (abstract of UI elements), which to locate and organize UI objects in a two dimensional page layout. However, the focus is not focusing on the design of physical page layout characteristic including the style, format, fonts, colors, size, etc. UI stereotypes have been defined according to UML extension mechanism to present UI elements. Each stereotype holds unique definition, functionality and presentation type. First, we describe the mapping rules for transforming navigation objects into UI presentation. Table 4 (see Appendix) shows the summary of these mapping rules. It provides mapping rules from Navigation Stereotypes to UI stereotypes. The symbol of arrow (→) represents mapping flow of UI stereotypes, and the symbol of two straight vertical lines (||) means an OR expression. We divide UI stereotypes into several categories, namely «UIPage» – to present web page layout, «UIInteraction» – to present web page that consist of interaction processes, «UIElement» – group of UI elements, «framePage» – to partition web page layout, «UILogin» – specific interface element to start interaction process, and

«UISession» – to describe interaction session. Table 5 (see Appendix) details each UI stereotype. In overall, User Interface Model (UIM) should describe what element of user interface objects should be considered, how many of them are getting involved, where they are resided on the page layout, which frame they are belongs to, and what happen if interaction processes took place between web users and hypermedia application.

## IV. Designing e-Library Application: A Case Study

An Online Library (e-Library) application is presented as the example through the whole contents of this paper. The idea is to illustrate how design efforts are taken to construct design models. In general, this application offers information about lecturers, researchers, authors, and publications. Publications are described by title, authors, abstract, publisher, and publishing date. Web users could also reach and browse author details. Thus, this application should provide appropriate and suitable navigation facilities to present the dynamic of navigation access from one navigation node to another navigation node. We consider book reservation process as an example of complex process. It is a functional operation invoked by web users with several sub-activities such as search, browse, and reserve book. The execution of this process will involve interactions between users and application. This process requires several activities to be carried out and it must respect to the flow of activities in the process. More functions and operations are provided in the application but this paper only focus those are related to complex processes and interactions modeling.

### *A. Modeling the Structure of Application Domain*

The first design effort is to define classes, objects, instances, and associations in the domain. According to [11], conceptual design should produce a model such as Class Diagram to build a domain model with no consideration of complex processes flow, navigations links, interactions processes, and user interface aspects. Information captured should be allocated in different classes (see Figure 2). This is done in iterative way so that all information requirements are modeled according to the requirement specifications.

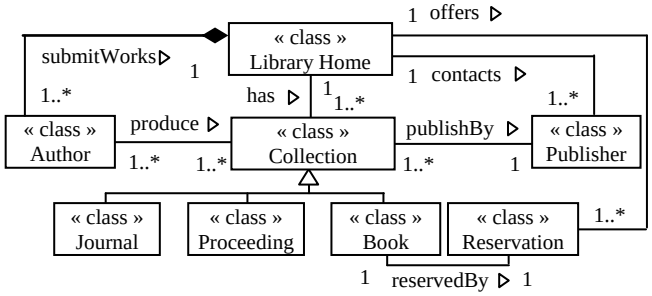


Figure 2. Conceptual Class Model (CCM)

According to Figure 2, several classes and associations have been defined through the standard of UML Class Diagram. It is called Conceptual Class Model (CCM). CCM illustrates high-level overview of general information in the application domain. For the sake of simplicity, we hide attributes and operations compartments in the diagram although there are many other aspects should be included. Information modeled in this stage will be detailed in next design stage to consider complex processes and interactions modeling.

### *B. Integrating Complex Processes*

We consider process of book reservation as complex processes since it is executed in sequence and iterative way that involved interactions with several conceptual classes within a same time. In this example, both atomic and non atomic processes are involved. These processes can be depicted in Figure 3.

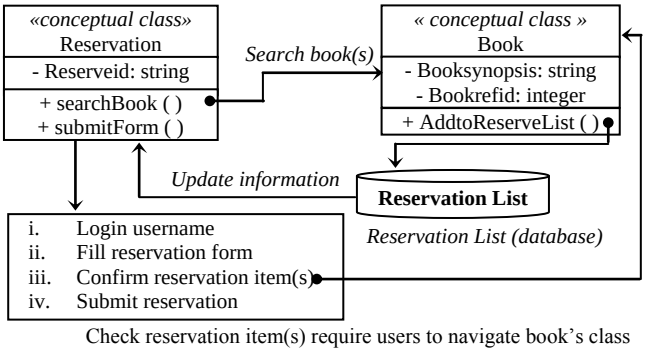


Figure 3. Atomic and Non Atomic Processes

Figure 3 presents atomic process and non atomic process in book reservation. Defining those processes would help designers to view the details of processes flow that reflect domain structure. According to [7] and [12], atomic process can be defined as a single operation performed by users. This operation is a standalone process that operated independently but it could also involve interaction that changes internal state of process that resides in other classes. In Figure 3, AddtoReserveList() is an atomic process that can change reservation state process in Reservation Class. The process is repeated depends on users' action. However, non atomic process is defined as a representation of processes sequence that comprises a number of sub-activities [7]. The execution of these sub-activities depends on users' actions or time duration for any process that waiting some events to be triggered. Book reservation process is the example of non atomic process since it comprises of sub-activities that has to be completed in sequence. Figure 3 illustrated the existence of non atomic processes in reservation class through submitForm() operation.

According to the example given in Figure 3, Conceptual Process Model (CPM) is constructed through UML stereotypes defined in Table 1. Figure 4 shows how CPM describes those complex processes. We can observe that both atomic and non atomic processes can be interleaved each other to complete a particular process. This is shown in reservation class and book class, where both classes provide appropriate links to present their relationships. Process link should provide physical link of navigation while action link provide logical link of navigation.

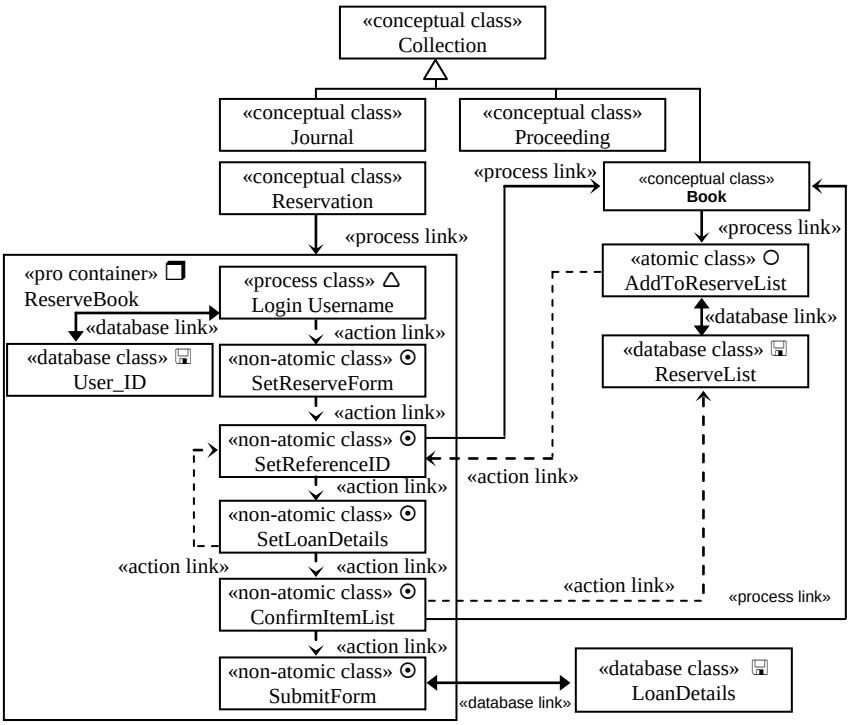


Figure 4. Conceptual Process Model (CPM)

The presentation of atomic and non atomic classes including process and action links defined through UML Profiles, give a clear and systematic view on how complex processes can be easily modeled through the proposed modeling approach.

### *C. Adapting Interaction Process in Navigation Design*

This section will present how conceptual classes, process classes and their associations in conceptual models are presented in navigational perspectives. According to Conceptual Class Model (CCM), classes that relevant to be considered as navigation classes are automatically defined as navigation classes. Any irrelevant classes can be eliminated from the model. Figure 5 shows how Navigation Class Model (NCM) constructed from conceptual design. It presents navigation classes, interaction classes, and hyperlinks that made possible for web users to reach.

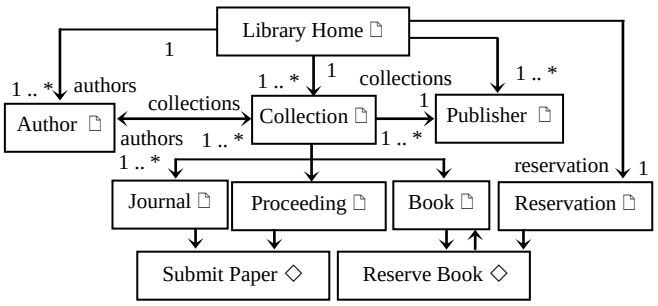


Figure 5. Navigation Class Model (NCM)

Com$^{+}$HDM introduces an interaction class to present interaction processes. In Figure 5, two interaction classes, namely submitPaper and reserveBook and they present interaction processes in NCM. Complex process flows captured in Conceptual Process Model shall reside in these interaction classes. Besides, hyperlinks should also be determined. It represents how navigation and interaction classes are physically linked and how web users can move across the nodes.

NCM must be enhanced into Navigation Access and Interaction Model (NAIM) to support navigation access mechanisms to present how navigation nodes can be visited by web users. The efforts of NAIM begin with employing menu items. There is no restriction on how many items should be defined in a menu. It will depend on navigation preferences and information requirements from web users. Once menu employed in NAIM, designers should determine access structures. Each access structure will present information in various forms of presentation. There are usually no errors of access structure selections, but it is important that designers can make a good decision on the best suitable access structures in the model so that web users can browse information in simple, easy, and faster way. Figure 6 illustrates NAIM. It describes and presents how navigation and interaction nodes in navigation space are reached through hyperlinks and access structures. According to the figure, we have provided example of all access structures we proposed in Table 3 to ensure the suitability and appropriateness of their implementation in the design model.

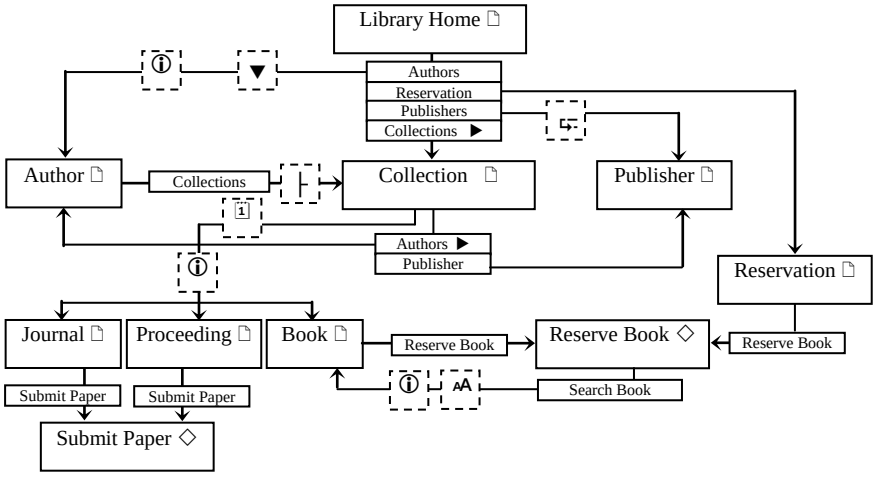


Figure 6. Navigation Access and Interaction Model (NAIM)

### *D. Mapping Navigation Objects into User Interface Elements*

User Interface (UI) elements should be employed to construct User Interface Model (UIM). We separate UI modeling efforts into two major parts – mapping navigation nodes and mapping interaction nodes. Both navigation nodes are derived from NCM through mapping rules and the descriptions of UI stereotypes. The structure of UIM however, can be varied depending on designer idea and decisions. For this example, each page is divided into several frame pages, and each frame contents several UI elements. Figure 7 illustrates UIM for library homepage and author page.

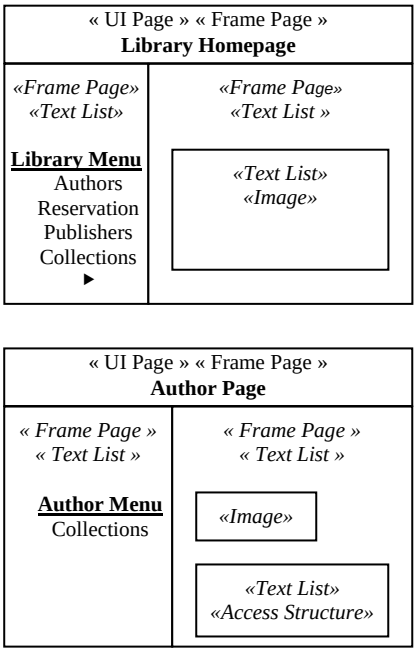


Figure 7. User Interface Models (UIM)

The construction of UIM focuses on providing presentational visual guidelines for developer to implement the real look of web application. It should provide descriptions of what should be presented and how those UI elements are located. Com$^+$HDM provides structural page layout presentation through logical layout characteristics, not physical characteristics. This section ends up overall discussions and main contributions of Com$^+$HDM towards the design of complex processes and interactions between web users and hypermedia application. In next section, we will summarize and discuss Com$^+$HDM in the context of design perspectives.

## V. SUMMARIES AND DISCUSSIONS

Design practices of web application require specific modeling approach to provide design models in systematic and comprehensive views. Com$^+$HDM includes three design models, namely conceptual, navigation, and user interface. Within these design models, we can examine how good the modeling approach could models a web application. In general, evaluation and validation of modeling approach can be done through two approaches and we employ these approaches to examine Com$^+$HDM. The first approach relates with case study example which has been presented in Section 4. The main objective is to analyze how models constructed could be implemented as real application. The results have shown that modeling elements provided in Com$^+$HDM are possible to model complex processes and interactions. We elaborated the details of modeling paradigm in each design stage and we present the results as design models according to the proposed modeling approach. The second approach is to compare Com$^+$HDM design features and modeling elements to several design dimensions. The idea is to capture how effective they are in modeling web application [20,21]. This approach is also known as design-oriented evaluation that is to evaluate internal strength of the design underlying the case

study application. Com+HDM is mainly required to describe the internal descriptions of particular application. From previous web example, design models constructed should be analyzed towards the definition of five major design dimensions, namely application contents, content's structure, user interface presentation, dynamics, and interactions [20]. These dimensions are mandatory, thus design methods should supports these dimensions to ensure web application built could successfully fulfill application's requirements. Table 6 (see Appendix) describes how Com+HDM supports those design dimensions. Each model constructed is considered as evaluation subjects to provide input and descriptions on the design features in relation to design dimensions. It also summarizes the descriptions on how design models in Com+HDM fully supports and satisfies the definition of hypermedia design dimensions. The details of each design model and given examples reflected to web case study prove the internal strength of the design features. Com+HDM modeling concepts equipped with various forms of precise and expressive stereotypes, thus it makes possible for designers to model web application in a successful way.

## VI. Conclusion

Com+HDM supports web design issues such as complex processes, interactions, navigation structures and access mechanisms, user interface layout, and so on. All these issues are tackled by the consideration of building design models at different stages of design lifecycle. Com+HDM is a model-based approach, that cover requirement analysis stage and three design stages. Designs are presented through models to provide precise information and detail the internal structures of certain application domain. Models constructed are separated in different design levels. However, they should complement each others in providing information at different design views. Thus, each model has its own design views and functionalities towards the completion of the whole design practices lifecycle. Models constructed are UML-based according to the general extension mechanism of UML Profile. It should provide easy and intuitive design paradigms in design practices. All modeling elements used have their own descriptive definitions, functionalities, and graphical notations; therefore it is easy for designers to understand models' views within their modeling specifications. Besides, Com+HDM offers powerful modeling features and facilities that could impose relationships from conceptual design views between objects and classes to facilitate navigation structures and user interface layout. These are made possible since all design stages comprises of their own expressive modeling elements. We can conclude our proposed modeling approach as a comprehensive, systematic, and flexible design method that is extremely useful and relevant to the current design and development practices in web engineering. The implementation and uses of UML Profile has made our proposed approach as comprehensive and easy-to-use by anyone. People who apply Com+HDM should require minimal knowledge of object oriented modeling technique – as it should supported by well known modeling notations and their expressive modeling elements. Com+HDM is a systematic design method since in every design stage we provide guidelines that assist designers to model particular domain of web application through the expressive, precise, and specific modeling elements. The design efforts are being performed in iterative and incremental approach, which could offers reusable models, maintenance aspects, and easy for error detection in those models. Com+HDM is a flexible approach because we believe in most web applications that contents complex processes and interactions, this modeling approach makes possible to model both atomic and non atomic processes. Once the processes have been captured and modeled, designers can easily translate the model into navigation structures to present how those complex processes reflect navigation mechanisms. However, some other design issues such as user personalization, reference model, adaptation, web security, and intelligent web system, are beyond of the scope of this paper. These issues can be considered as future refinement works in Com+HDM to cover more and more design concepts and supports a bigger scope and higher scale of web applications.

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# APPENDIX

TABLE 1. UML STEREOTYPES IN CONCEPTUAL PROCESS DESIGN.

| **Specific Modeling (Notational) Elements of a Conceptual Process Model** | | |
|---|---|---|
| **Name** | **Notation** | **Descriptions** |
| Process Class | «process class» △ | Defined as the similar way as action taken by users to perform an activity. The instances or objects of process class are used by users during the execution of a sequence of pre-defined processes. |
| Atomic Class | «atomic class» ○ | Inherit *process class*. It is a single process that can be performed and executed independently as one operation/process. |
| Non Atomic Class | «non atomic class» ⊙ | Inherit *process class*. The execution of *non-atomic* must be performed in sequential order (they might have dependencies). |
| Database Class | «database class» | Model the existence of database in application domain. It provides a logical view of database operations between *process class (atomic class and non-atomic class)* and *database class*. |
| Process Container | «pro container» ❒ | Group and partition *process class* in order to indicate their relationship or dependencies. It is to determine which partition an instance of processes belongs to. |
| Process Link | «process link» ⟶ | Association between two separated classes; *conceptual class* to *process class* and vice versa. Also known as *external link* that connects those classes through navigations. |
| Action Link | «action link» - - - - -> | Association between operations in the same process class (process class to process class). It is to indicate dependencies of processes and information flow in particular process class. |
| Database Link | «database link» ⟷ | Association between *conceptual class* or *process class* and *database class*. Represent the information and data operations such as query, lookup, entry, etc. |

TABLE 2. UML STEREOTYPES IN NAVIGATION CLASS DESIGN

| **Modeling (Notational) Elements of Navigation Class Model** | | |
|---|---|---|
| **Name** | **Notation** | **Descriptions** |
| Navigation Class | «navigation class» 🗋 | Conceptual classes (in CCM) that are closely relevant to the application domain derived as *navigation class.* It presents the existence of navigation node in navigation hyperspace. |
| Interaction Class | «interaction class» ◇ | Present the existence of interaction processes in navigation hyperspace. Interaction class must always have at least a reference to a navigation class. |
| Navigation Link | «navigation link» ⟶ | Also known as *hyperlink*. Derived from associations in Conceptual Class Model. |

TABLE 3. UML STEREOTYPES IN NAVIGATION ACCESS STRUCTURE DESIGN

| **Modeling (Notational) Elements of Navigation Access and Interaction Model** | | |
|---|---|---|
| **Name** | **Notation** | **Descriptions** |
| Index | «index» ⓘ | An index contains a number of arbitrary listed name items with a link to a target navigation class. Every item has its own unique name and owns a link (target) to any instances of a navigation class. |
| Tree | «tree» ├ | Tree provides a hierarchical structure view of a complex index structure. The menu can be expanded or collapsed (for best orientation). |
| Text Query | «text query» AA | An interactive text input item that provides an input field to search information. Users need to provide a keyword as input. |
| Selectable List | «selectable list» ▼ | Selectable list provides easy-to-go navigation facility. Several listed input items are provided and they are frozen. It gives more guidance for web users as search mechanism. |
| Guided Tours | «guided tours» | Guided tour provides an ordered sequential access to a number of navigation nodes or instances. The sequences have been defined to enforce a sequence of navigation class presentation. |
| Page | «page» | Page provides direct access to a group of instances in a navigation class. The page items are grouped and numbered and each of them has its own link to a target instance location. |
| Menu | «menu» | Menu provide composite objects (homogeneous) of menu items which have fixed name (frozen) and own a specific link to navigation target class, interaction class, or other access structures. |
| Trail Menu | «trail menu» ▶ | Trail menu is a menu with several sub-items. It can be expanded and collapsed in order to provide dynamic view and faster access of menu. |

TABLE 4. MAPPING RULES TRANSFORMATION

| **Navigation Stereotypes** | ***Map to* – User Interface Stereotypes** |
|---|---|
| «navigation node» | «UIPage» → «framePage» → «UIElement» |
| «interaction node» | «UIInteraction» → «framePage» \|\| «UILogin» → «framePage» \|\| «UISession» \|\| «UIElement» |
| «navigation link» | «accessStructure» \|\| «hyperlink» \|\| «formElement» |
| «access structure» | «UIElement» → «accessStructure» \|\| «multimediaElement» \|\| «formElement» |

TABLE 5. UI STEREOTYPES IN USER INTERFACE DESIGN

| **UI Stereotypes** | **Descriptions** |
|---|---|
| «UIPage»<br>User Interface Page | Models the presentation of a navigation node. It reacts as a page that views information, hyperlinks, and access structures. It can be partitioned to locate or separate specific information for easy viewing purposes. |
| «UIInteraction»<br>User Interface Interaction | UIInteraction reacts as a page that contains interaction processes. This is a specific node that views how transactions and operations can be performed. |
| «framePage»<br>Frame Webpage | Frame partitions web page into different presentational areas. It separates web page to relocates any information for simple and separated viewing look. |
| «UILogin»<br>Login Interface | It is a specific node to start interaction process which requires web users' identification or authentication. |
| «UISession»<br>Session Interface | Interaction processes should be kept as a session. UISession provides a notation to relate any UIPage that involved in particular interaction session. |
| «UIElement»<br>User Interface Element | UIElement gathers all interface elements which contribute to the construction of a web page. It is composed by another three stereotype's groups, namely Access Structure, Multimedia Element, and Form Element. |

TABLE 6. COM$^+$HDM DESIGN MODELS IN RELATION TO HYPERMEDIA DESIGN DIMENSIONS

| **Design Dimensions** | **Com$^+$HDM Design Models and Descriptions** |
|---|---|
| Application contents | **Conceptual Class Model** – provide general information in the context of UML Class Diagram including its properties such as classes, attributes, relationships, and operations according to information requirements from users.<br>**Conceptual Process Model** – provide the details of complex processes information and the contents of processes flows. |
| Content's structure | **Conceptual Class Model** – Associations and relationships in the model react as the main mechanism to present application structure.<br>**Navigation Class Model** – «navigation links» provided in this model react as the main navigation facility and they present how classes (nodes) in the application domain are clearly structured. |
| User interface | **Navigation Access and Interaction Model** – This model is closely relates to final presentation of application in the context of «navigation node», «interaction node», and «access mechanism».<br>**User Interface Model** – This model provides a logical visualization view of «UIElement» that are transformed from navigational objects through mapping rules formulation. |
| Dynamics | **Navigation Class Model** - «navigation links» offers hyperlinks to allow user to move from one navigation node to another. All classes are linked via hyperlinks represented by directed arrow.<br>**Navigation Access and Interaction Model** – Access structures presents how navigation nodes are reached by users with various forms of navigation access facilities. |
| Interactions | **Complex Process Flow Model** – Flow of activities that performed by users are captured in the presentation of UML Activity Diagram.<br>**Conceptual Process Model** – Presents the flow of complex processes and interaction of class model. This model provides presentational view on how interactions are performed in the domain structure of the application.<br>**Navigation Access and Interaction Model** – Provide high level presentation on how interaction nodes can be integrated in navigation structure scheme within its access structure mechanisms. |