ADAPTIVE MODEL FOR WEB ENGINEERING METHODS TO DEVELOP MULTI WEB APPLICATIONS IN AGILE ENVIRONMENT

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DEDICATION

Dedicated to my beloved family and best friend who has always believed in me.

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ABSTRACT

Model Driven Web Engineering (MDWE) is an application of a model driven paradigm in the domain of web software development. MDWE is helpful because technologies and platforms of web applications constantly evolve into Web Engineering Methods (WEMs). The evolution of web applications has consequently introduced new features and challenges, therefore existing WEMs need to be improved. These WEMs have failed to develop modern web applications' features. Furthermore, no single WEM is capable of covering the whole lifecycle phases. These issues decrease the usability. In addition, the Interaction Flow Modeling Language (IFML) as a recent method has also not been able to address them. This thesis developed a new WEM, Useable Adaptive Agile IFML (UAA-IFML) to solve these issues in several steps. In this research, mixed methods used were qualitative and quantitative methodologies. In the first step, a new adaptive model was defined for supporting the features of multi-web applications. The new model was developed via an adaptive model into the IFML metamodels known as Adaptive IFML (AIFML). In the second step, IFML was enriched through MockupDD for covering lifecycle, known as Agile IFML (A-IFML). This is because MockupDD provides an agile environment, hence agile lifecycle can solve the lifecycle issue. In the third step, a new adaptive model and agile process were combined as Adaptive Agile IFML (AA-IFML). This integration increased the usability of the IFML method. In presenting the usability of AA-IFML, experimentation of the framework was extended to evaluate the usability of WEMs. Besides, feedbacks on the usability of AA-IFML were obtained from developers around the world using three instruments, namely performing tasks, answering questionnaires, and interviewing experts. Analysis on the feedback indicated a 20% improvement usability of the AA-IFML compared with current IFML. The findings have shown that the UAA-IFML is beneficial for developers, as they would only need to use one method to design modern web application features in the whole lifecycle phases.

ABSTRAK

Model Pemacu Kejuruteraan Web (MDWE) ialah aplikasi paradigma model pacuan dalam pembangunan sistem web. MDWE berguna disebabkan oleh perkembangan teknologi dan aplikasi web yang berterusan melalui kaedah Kejuruteraan Aplikasi Web (WEMs). Perkembangan aplikasi web menyebabkan timbulnya ciri dan cabaran baharu, maka WEMs sedia ada perlu diperbaiki. WEMs ini gagal untuk membangunkan ciri aplikasi web moden. Di samping itu, tiada satu pun WEM yang mampu untuk menyokong keseluruhan fasa kitaran hayat. Isu ini mengurangkan kebolehgunaannya. Selain itu, Bahasa Pemodelan Interaksi Aliran (IFML) yang merupakan kaedah terkini juga tidak dapat menangani isu tersebut. Tesis ini mencadangkan WEM baharu, Agil Suai Boleh Guna IFML (UAA-IFML) untuk penyelesaian isu ini dalam beberapa langkah. Kajian ini menggunakan kaedah campuran, iaitu metodologi kualitatif dan kuantitatif. Langkah pertama, model adaptasi baharu ditakrifkan untuk menyokong fungsi aplikasi kepelbagaian web. Model baharu ini dicadangkan dengan memperkenalkan model adaptasi ke dalam metamodel IFML yang dikenali sebagai Adaptasi IFML (AIFML). Dalam langkah kedua, IFML diperhebatkan dengan MockupDD yang boleh meliputi kitaran hayat yang dikenali sebagai Agil IFML (A-IFML). Ini adalah kerana MockupDD menyediakan persekitaran agil dan mempunyai kitaran hayat agil yang boleh menyelesaikan masalah kitaran hayat. Dalam langkah ketiga pula, model adaptasi baharu dan proses agil digabungkan, sebagai Adaptasi Agil IFML (AA-IFML). Integrasi ini meningkatkan kebolehgunaan kaedah IFML. Dalam membentangkan kebolehgunaan AA-IFML, satu rangka kerja diperluas untuk menilai kebolehgunaan WEM. Di samping itu, maklum balas terhadap penggunaan AA-IFML diperoleh daripada pemaju di seluruh dunia melalui tiga instrumen, yang dinamakan sebagai pelaksanaan tugas, menjawab soal selidik, dan temu bual pakar. Analisis maklum balas menunjukkan peningkatan kebolehgunaan AA-IFML sebanyak 20% berbanding dengan IFML yang sedia ada, Hasil kajian menunujukkan UAA-IFML bermanfaat kepada pemaju kerana hanya perlu menggunakan satu kaedah untuk mereka bentuk ciri web aplikasi moden yang meliputi keseluruhan fasa kitaran hayat.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AA-IFML	-	Adaptive Agile IFML
AAU-IFML	-	Adaptive Agile Usable IFML
ADV	-	Abstract Data Views
AI	-	Artificial Intelligence
AIFML	-	Adaptive IFML
A-IFML	-	Agile IFML
API	-	Application Programming Interfaces
ASD	-	Adaptive Software Development
AWA	-	Adaptive Web Application
AWE	-	Agile Web Engineering
BPMN	-	Business Process Modeling Notation
CIM	-	Computer-Independent Model
CM	-	Code Model
CMS	-	Content Management System
DD	-	Diagram Definition
DI	-	Diagram Interchange
DIS	-	Dynamic Interactive Systems
DOM	-	Document Object Model
DSDM	-	Dynamic Systems Development Method
EBSE	-	Evidence-Based Software Engineering
EMF	-	Eclipse Modeling Framework
EORM	-	Enhanced Object-Oriented Relationship Methodology
ET	-	Equivalent Transformation
FDD	-	Feature Driven Development
GUI	-	Graphic User Interfaces
HCI	-	Human Computer Interaction
HDM	-	Hypermedia Design Method
HTML	-	Hypertext Markup Language
HTTP	-	Hypertext Transfer Protocol
IFML	-	Interaction Flow Modeling Language

IT	-	Information Technology
IWA	-	Intelligent Web Application
MDA	-	Model Driven Architecture
MDD	-	Model-Driven Development
MDE	-	Model-Driven Engineering
MDWD	-	Model Driven Web Development
MDWE	-	Model Driven Web Engineering
MockupDD	-	Mockup Driven Development
MVC	-	Model-View-Controller
MWA	-	Mobile Web Application
NDT	-	Navigational Development Technique
OMA	-	Object Management Architecture
OMG	-	Object Modelling Group
OOH	-	Object Oriented Hypermedia
OOHDM	-	Object-Oriented Hypermedia Design Method
OOWS	-	Object Oriented Web Solutions
OWL	-	Web Ontology Language
PDA	-	Personal Digital Assistants
PIM	-	Platform-Independent Models
PSM	-	Platform-Specific Models
QoS	-	Quality of Service
RDF	-	Resource Description Framework
RIA	-	Rich Internet application
RMM	-	Relationship Management Methodology
RQ	-	Research Question
RUX	-	Rich User eXperience Method
SeRQL	-	Sesame RDF Query Language
SOA	-	Software Oriented Architecture
SPEM	-	Software and Systems Process Engineering Metamodel
SPU	-	Sulaimani Polytechnic University
SUI	-	Structure User Interface
SWA	-	Semantic Web Application
SWEBOK	-	Software Engineering Body of Knowledge

SWIS	-	Semantic Web Information Systems
TDD	-	Testing-Driven Development
UHD	-	University of Human Development
UI	-	User Interface
UML	-	Unified Modeling Language
UR	-	Usability Rating
URI	-	Uniform Resource Identifiers
UTM	-	Universiti Teknologi Malaysia
UWA	-	Ubiquitous Web Applications
UWE	-	UML-Based Web Engineering
W3C	-	WWW Consortium
W3C	-	World Wide Web Consortium
WAD	-	Web Application Development
WE	-	Web Engineering
WebML	-	Web Modeling Language
WEBOK	-	Web Engineering Body of Knowledge
WebRE	-	Web Requirements Engineering
WEM	-	Web Engineering Method
WI	-	Web Information
WIS	-	Web Information System
WSDM	-	Web Site Design Method
WUEP	-	Web Usability Evaluation Process
WWW	-	World Wide Web
XML	-	Extensible Markup Language
XP	-	eXtreme Programming

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Overview

Web applications currently make up one of the largest growth areas in software. Web applications do not just give us new types of applications but provide an entirely new way to deploy software applications to end users. Recent web applications are primarily constructed to produce applications that possess enriched interactivity from high-quality requirements, achieved through employing modern programming models, languages, and new technologies. Modern web applications are distinguishable from legacy web applications, regarding sophistication and rich program interactivity requirements. Modern web applications are often presented with modern Graphic User Interfaces (GUI) as well as innovative incorporations of backend technologies (Andrews et al., 2005).

Evolution of Web 1.0 into the Web 4.0 (Aghaei et al., 2012) and sometime new web is Web 5.0 (Algosaibi et al., 2017) of the World Wide Web (WWW), has resulted in the introduction of several web applications (Story, 2015). Categorization and evolution of web applications' complexity have been reported in (Kappel et al., 2006b), whereas, scholars in (Spivak and Tucker, 2007) have grouped web application types based on the chronological order of their appearance. Figure 1.1 presents the history of complexity and generations of web and popular web applications, in this thesis imported Web 5.0 to Web 4.0 because of both generation regarded to Artificial Intelligent (AI). Clusters of Web 3.0 and 4.0 represent modern web applications that possess great extent of complexities, encompassing Ubiquitous Web Applications (UWAs), Rich Internet Applications (RIAs), Semantic Web Applications (SWAs), and Intelligent Web Applications (IWAs).

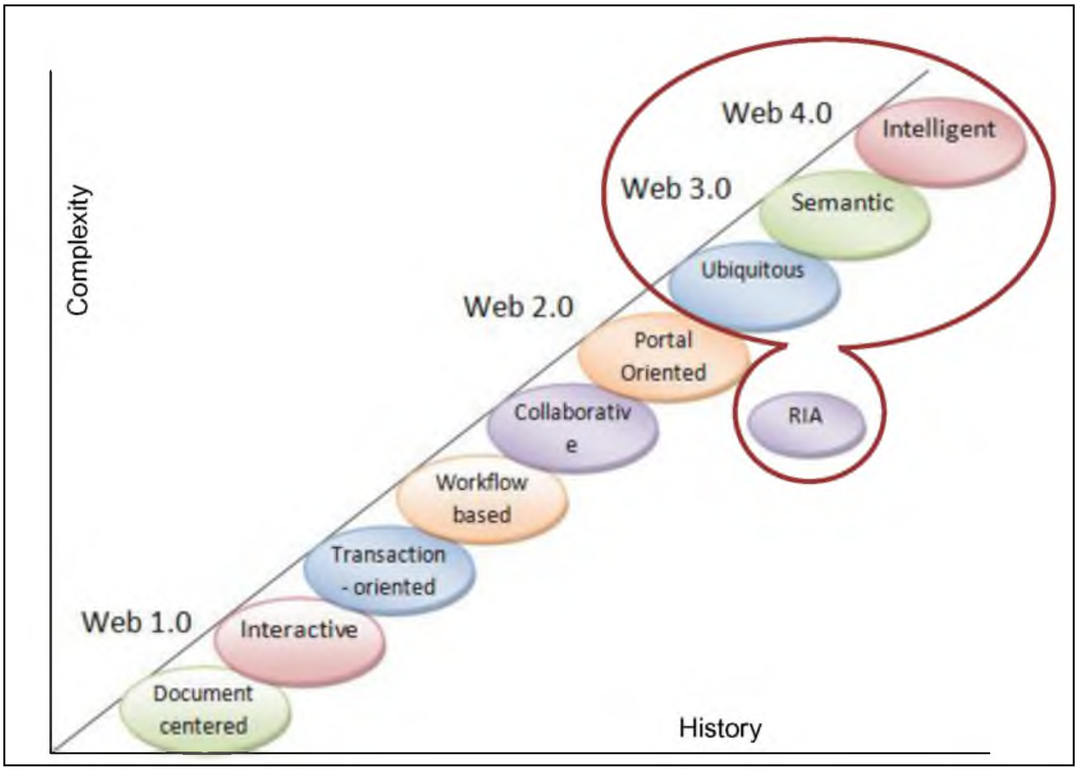

Figure 1.1 Chronological Order of Web Evolution and Complexity

Model Driven Web Engineering (MDWE) is deployed based on the concept of separation of representation models in designing web applications, which is advantageous, predominantly, as the platforms and technologies employed in developing web applications continue to evolve (Aragón et al., 2013a; Aragon et al., 2012; Escalona et al., 2011; Kraus, 2007; Kraus et al., 2007). Best practices and trends of a number of MDWE strategies were investigated in the work of Jesús and John (2012) (Hincapié Londoño and Freddy Duitama, 2012). The work reported the merits and drawbacks of each MDWE strategy and made recommendations prior to initiating Web Application Development (WAD), which include: identifying web application type, considering the possibility of architectural changes, and identifying the latest technology that could deliver a sophisticated User Interface (UI). The work presented deep insights on the future development of web applications through MDWE consideration.

The schemes used in improving modern web applications; through utilizing Web Engineering Methods (WEMs) include the amalgamation of notations and development process, often bundled into a metamodel. Various metamodels have been developed to cater for different web domains. In the construction of a semantic web, it is pertinent to observe the association of metamodels and their elements that conform to established grammatical rules. WEMs that are constructed based on several metamodels, typically, only utilizes a portion of the build offered from each metamodel. This allows several modeling rules to be unified forming base metamodels, which support improved comparison and integration (de Koch, 2001). Development and construction of complex web applications are aided by rich modeling features offered in various WEMs, including IFML, WebML, W2000, UWE, OOHDM, and OOH. Across all WEMs, three generic representations are typically covered, including presentation, navigation, and conceptual representations (Wakil and Jawawi, 2014b).

Existing web application projects emphasize on the adaptation of navigational and presentational attributes of WEMs, in order to deal with user multiplicity and diversity, for example; De Bra et al. (2003) explored a WEM that incorporates adaptive techniques to promote the systematic development of Adaptive Web Applications (AWA), by integrating the knowledge of adaptive hypermedia (De Bra et al., 2003) and web engineering (Mendes and Mosley, 2006), which have been implemented with much success in traditional hypermedia systems. Adaptive applications have been demonstrated to be effective in informing user's current navigation location in the structure of web application, which helps them to determine suitable further navigation decisions (Brusilovsky, 2004) as well as preventing the application from providing users with excessive information during that period (Bra, 2000).

Towards improving the quality of web application development, web engineering development process must be put into an agile environment. In light of this, in 2001, Agile Web Engineering (AWE) process was introduced to produce streamlined processes for effective web development. The AWE process deals with issues including brief development lifecycle time, diverse development team members composing of different specializations and effective construction of customized web applications that incorporate data and software. Additionally, AWE process emphasizes analysis of requirements, particularly: concise business needs analysis, improved testing and assessment on development artifacts, and deep considerations on challenges that are related to web-based applications evolutions (McDonald and Welland, 2001a).

Quality is critical to satisfying customers. Product quality of WAD assessed from a usability point of view. Usability refers to the extent of ease of use of a product that is experienced by users. Methods that improve ease of use in design process also refers to usability (Insfran and Fernandez, 2008). There are several shortcomings with the existing web usability evaluation approaches such as the concept of usability is only partially supported; usability evaluations are mainly performed when the web application has been developed; the lack of guidelines on how to properly integrate usability into web development, and the shortage of Web usability evaluation methods that have been empirically validated. For example, Fernandez et al. (2013) (Fernandez et al., 2013) proposed a usability evaluation method that called Web Usability Evaluation Process (WUEP), that can be integrated into different MDWE processes, through this method, they addressed the aforementioned limitations of usability evaluation WEMs.

1.2 Problem Background

Existing methods of web engineering face greater challenges attributed to the birth of modern web applications that evolve rapidly, which are highly complex. This has broadened the existing knowledge gaps for web applications further, which are, therefore, worthwhile to be explored. Remaining issues of web engineering surround lifecycle and adaptability challenges. In this section, web applications and web engineering will be described. Web applications section elaborates modern web applications' complexity issues. Meanwhile, web engineering section describes open challenges in developing modern web applications utilizing existing WEMs.

1.2.1 Web Applications

The rapid proliferation of websites has allowed users to access various online alternatives to information. Latest Netcraft (2018) survey reported, as of May 2018, there exist 1.8 billion web sites that are available to be accessed by users (Netcraft, 2018). Together with the growth explosion, the complexity of websites also grew significantly. The complexity saw a rapid increment in terms of the number of innovative and multiple interactive functionalities that are present on a website. Earlier websites had limited functionalities, with predominantly static pages, had steadily advanced into highly complex web applications with numerous interactive features. Modern web applications offer rich content to users, which are sourced from multifaceted data repositories.

The earliest WWW sites introduced in 1989 were engineered to provide read-only information to users, with site contents delivered in plain pages. Attributed to the rapid evolution of web sites into web applications, the complexity of these applications increases at a rapid pace. This is true for interactivity and workflow-based applications, which are complex as they are often supplemented with support systems that assist end users in performing numerous activities.

Web applications are categorized based on the chronological order of their appearance and their complexity levels (Kappel et al., 2006a). In recent years, web applications have grown complex significantly, attributed to the proliferation and maturity of mobile technologies, which have made it possible to access web sites with rich contents on different devices. This gave rise to a new category of web applications, known as UWA. UWAs enable web accessibility to be achieved by users; virtually anywhere around the globe, across desktop-based and mobile-based devices, regardless of the difference in their technological capacities.

Modern web applications are able to balance the quality of rich content delivered to users, attributed to the capability of semantic web that is able to assess and compare: requests from clients and the currently available resources that could fulfill the requests. Semantic web shapes the foundation for applications that possess self-cognizance. In recent years, the stability of SWA has slowly reached maturity, with added essential components that adhere to established standards. The growth of semantic web is gradually having a stronger influence on human daily routines. While some semantic web applications have been developed and deployed with much success, numerous others are still under construction. Moving forward, semantic web could be effectively used to serve the needs of different web application domains. Even as semantic web demonstrates intelligence, it is distinct from next-generation AI. Despite the capability of semantic web to reason based on certain parameters, an ideal solution of semantic web that solve all problems is not an entirely possible pursuit. The following revolutionary applications could shift our established understanding on the breadth of capability of computers in the near futures (Tjoa et al., 2005): 1) Augmented personal memories that exhibit semantic reasoning. 2) Combination of the wisdom from the entire world in a single machine that could be accessed easily. 3) Incorporation of services from semantic web into user web applications.

In terms of UI interactivity and usability, much improvement is needed for web applications. RIAs have been introduced, in reaction to this, which allows UI to be enriched with interactive and efficient graphical elements, emulating the appearance of UI in desktop machines. Specifically, RIAs offer improved user interaction experience in using application functionalities as well as improved responsiveness. RIAs' functionalities closely resemble the application' functionalities that are made available in desktop mode. The earliest appearance of Internet applications' GUI was presented in plain and static Hypertext Markup Language (HTML) pages. Despite being satisfactory in delivering basic functionalities to users, these HTML pages lack the feel and look of a desktop application (Busch and Koch, 2009a; Choudhary, 2012). The UI one of the main steps for being a developer as presented by (Foster and Green, 2019), furthermore UI one of the challenges for the web developer. The developer should be controlled the quality of applications and increasing usability through UI (Choma et al., 2016).

Conventional web applications are enriched by RIAs via the following strategy: Supplementing additional processing power to client-side scripting (i.e. JavaScript). Client-side scripting allows user interaction (known as an event) to be executed efficiently. Instances of events include time-out and mouse click by users.

Through client-side scripts, web pages may be manipulated and accessed by utilizing a dedicated interfacing component that is independent of the language and platform that are used, known as Document Object Model (DOM) (Busch and Koch, 2009a).

Web applications are constantly modernized, owing to the introduction of various innovative features with greater complexity; in the wake of rapid technological advancement. In spite of this, the WEMs and tools used for modern web applications remain ill-equipped. In this light, in developing modern web applications, a concerted effort needs to be geared to enhance WEMs to support modern web applications development. In the next section, WEMs will be reviewed as well as gaps will be highlighted in the process of web applications development.

1.2.2 Web Engineering

WEMs have been regularly improved to meet the requirements of new technologies in developing and implementing web systems. As technologies supporting web systems evolve, also have the adaptation and extension of existing methods, in terms of; new or improved models, transformation, and processes that would integrate new aspects or concerns.

Primarily, Model Driven Web Development (MDWD) splits the design of web application into three models: content, navigation, and presentation models. These models separate the implementation of a web system in different abstraction level (Casteleyn et al., 2009). Through MDWD, models are transformed, regardless of the implementation details. For instance, MDWD strategy converts platform Independent Models (PIMs) such as structural models, navigational models, or abstract UI models into further models which possess explicit aspects of a platform-dependent technology, i.e. Platform Specific Models (PSMs) such as concrete UI models or database schemas. The conversion is achieved through adhering to transformation constraints. PSMs could be used to produce source code template that represents the web application Code Model (CM). Subsequently, additional methods are executed, such as Object-Oriented Hypermedia (OO-H) (Gómez et al., 2001) or Web Modeling Language

(WebML) (Ceri et al., 2000). Through establishing traceability among these models (PIMs, PSMs, and CMs), the assessment of trace links would be able to yield usability issues that may surface in the final web application. Further, suggestions or corrections could be generated, which allow correctional efforts to be executed in the early phase of web development process. MDWE recommends concept representation through utilizing metamodels as they are applicable to all development platforms. The development process is supported by a set of transformations and relations among concepts that enables agile development and assures consistency between models.

MDWE could be utilized to effectively solve open challenges in web development. The diversity of methods used in development, due to poor enforcement of development rules, is an open challenge that could be solved via MDWE. Through enforcing a single MDWE standard, a mix-and-match strategy in using methods could be prevented from being exploited by developers. As reported by Lang and Fitzgerald (2006) (Lang and Fitzgerald, 2006), there are as many as fifty WEMs in existence. Undoubtedly, as highlighted in several reports, each method has its own merits and drawbacks (Barry and Lang, 2001; M.J. Escalona, 2007; M.J. Escalona, 2004; Schwinger et al., 2008).

One of the open challenge faced by the current WEMs lies in an incomprehensive coverage of improvement lifecycle that could not be covered solely by utilizing one method. It was suggested that a mixture of three methods was required in covering a complete web development lifecycle (Aragón et al., 2013b). Despite this, method mixing is vulnerable to technical challenges as well as offers poor values to web development. In mediating the weaknesses of the current WEMs. The AWE process concerns with issues surrounding web development, including brief development lifecycle period; team members comprising different specialization areas; and delivery of customized solutions incorporating data and software. Additionally, AWE process emphasizes analysis of requirements, particularly: concise business needs analysis, improved testing and assessment on development artifacts, and deep considerations on challenges that are related to web-based applications evolutions (McDonald and Welland, 2001a).

Recently, as an attempt for solving this issue Mockup Driven Development (MockupDD), which is a model-driven strategy that provides agile software development for MDWE practices was proposed (Rivero et al., 2014). An extension of earlier work, MockupDD was hybridized with a Scrum agile process by Riverio and Rossi (2013) (Rivero and Rossi, 2013). MockupDD constructs prototypes of user interfaces adhering to the features of web application that will be developed. The UIs are constructed based on vigorous feedbacks from customers of the application. Subsequently, these prototype user interfaces would be transformed into an abstract UI model, which supports MDWE model transformation or other transformation that are specific platform requirements.

Despite the significance of adaptability in web engineering, there is a dearth of literary evidence that investigates on the issue. Rohas (2008) proposed adaptive primitives, which allow well-known adaptive methods to be expressed at top concept levels. These primitives are compatible with user modeling applications. Despite this capability, there exist numerous methods that allow the integration of adaptive methods through several options in Object-Oriented Web Solutions (OOWS) navigational plans. In order to facilitate modeling through adaptive features, requirements model needs to be defined, which subsequently assists the construction of adaptability requirements that are specific for the model, in addition to information requirements that are associated with the end users of the application (Rojas, 2008).

Adaptability consideration exists in various domains including web application and software engineering domains (i.e., adaptability of web browsers, methodologies, and devices). Adaptability in web engineering is considered across different representations: content, navigation structure, and presentation (Filman et al., 2004). Existing WEMs lack adaptability in terms of supporting modern web applications. In the wake of this, scholars have proposed solutions via extension or combinations of existing methods which support RIA, including combined UML-based Web Engineering (UWE) with Rich User eXperience Method (RUX-Method) (Preciado et al., 2008), extended UWE (Machado et al., 2008), and extended WebML for RIA (Fraternali et al., 2010). In addition, a method to design a semantic web was proposed by Hera (Houben et al., 2003). Meanwhile, Hemida (2013) proposed a method supporting semantic web and RIA, among all extension for Hamida's work best extension but also could not support all types of web applications. In light of this, an extension to UWE method was performed, by considering eleven additional elements in presentation model and navigation model, which was later shown to be still insufficient in supporting evolving web application features (Said, 2013; Wakil et al., 2014b). Furthermore, IFML as recent web engineering method and it is famous as an interaction method but also could not succeed in the process development features modern web applications, however some works solved this issue partially bet could not solve it concretely, for example Laaz and Mbarki (2016) combined ontology with IFML for importing ontology feature to IFML (Laaz and Mbarki, 2016), in another work Brambilla et al. (2017) enhanced IFML flexibility for recognizing the new concern from web applications (Brambilla et al., 2017). Moreover, Rossi et al. (2016) highlighted several weaknesses in overall web engineering methods (Rossi et al., 2016). These works approved that original IFML failed in the process development features modern web applications.

Web engineering is an emerging discipline that focuses on bridging the gaps that exist in the development of modern web applications. In recent years, noteworthy advancements have been and continue to be achieved in transforming web engineering into a branch of engineering that concentrates on web applications' design, development, evolution, and quality (Mikkonen and Taivalsaari, 2010; Rio and e Abreu, 2010). In general, web engineering has been formally defined as the solicitation of systematic discipline and engineering strategies leading to effective development, deployment, and maintenance of high-quality web-based systems (Ali and Ahmad, 2015). Past studies of web engineering encompassed various issues of Human-Computer Interaction (HCI) including the methods that could be used to evaluate usability of web systems (Fernandez et al., 2013). Web engineering typically covers the areas of development, enhancement, and extension of; methods, techniques, and tools, that are responsible in assisting developers in developing web applications (Torrecilla-Salinas et al., 2016).

1.3 Problem Statement

The existing web development processes could be further improved, attributed to the lack of the presence of state-of-the-art WEMs, which could tackle the rapid evolution of web applications. There are a number of gaps that have been discovered from the literature of WEMs. Past research has mostly extended existing WEMs, either through combining two methods or through creating a new method that streamlines the process of developing new concerns of web applications. Even Interaction Flow Modeling Language (IFML), which is the most recent and promising interaction method, with extensive ten-year experience on WebML, fail to address the issues surrounding the development of modern web applications. In this thesis, three main problems surrounding web applications are justified through the development of a solution that emphasizes lifecycle, adaptability, and usability.

Web applications constantly evolve, which as a result, generate new breeds of web applications, having additional features such as UWA, RIA, SWA, and IWA. Existing studies primarily concern with either; improving the current WEMs or defining a novel variant of WEM with new concerns. Such trends would foresee an endless birth of new web application types, owing to the continuous development of web technology. The main issue, which should be focused, underlies in investigating the adaptive model in WEMs for supporting a diverse variety of web applications. The model should ideally support all features across all types of web applications dynamically. In addition, the model should be used as a de facto standard in defining and supporting new web applications in the future.

Another issue in current WEMs revolves around lifecycle. At present, no single WEMs to cover the whole lifecycle phases. Existing methods presented have merely focused on either; a phase, or two phases of web engineering lifecycle. Currently, developers have the tendency to utilize either; two, or more methods in order to cover the entire lifecycle, in addition to utilizing Unified Modeling Languages (UML) to solve this issue. This open problem calls for a solution that either; defines or improves new methods as some consideration such as adaptability is unlikely to be fully present without a complete web engineering lifecycle.

The aforementioned problems are difficult to be quantified without the consideration of usability evaluation. Increasing usability measures could be deemed as reflecting the quality of the methods. In the wake of increasing challenges of WEMs, the usability measure is likely to show a decreasing trend. For this reason, usability needs to be improved with meticulous attention given to the aforementioned problems. Consequently, such usability evaluation could become a de facto standard for state-of-the-art WEMs. This thesis defines a new adaptive model for IFML, through developing multi-web application features and agile IFML for solving lifecycle issues. Consequently, a new adaptive model would be developed, integrating agile considerations for increasing usability.

The Research Questions (RQ) for this study are derived based on the statement of problems and research objectives. The primary RQ for this research is:

"How to define an adaptive model in the lifecycle to increase IFML usability?"

In addition to the primary RQs, several secondary RQs associated with this research are raised as follows:

(i) How to extract the features of modern web applications?
(ii) How to identify the weaknesses and strengths of WEMs?
(iii) What are the adaptability considerations for multi-web applications?
(iv) How to propose a new adaptive model for new WEM?
(v) How to implement agile web engineering covering lifecycle?
(vi) How to integrate adaptive model with an agile process?
(vii) How to present the usability of the new method?
(viii) Which framework is capable of usability evaluation of WEMs

1.4 Research Objectives

This research proposes a new WEM for developing multi-web applications covering the whole phases of web engineering lifecycle. The objectives proposed to achieve this goal are as following:

(i) To analyze modern web applications in order to extract features based on WEMs.
(ii) To propose a new adaptive model for IFML in developing multi-web applications.
(iii) To incorporate agility to IFML by using MockupDD covering the whole phases of web engineering lifecycle.
(iv) To integrate a new adaptive model with agile processes of IFML.
(v) To propose usability evaluation framework for the new WEM.

1.5 Research Scope

The scope of this research study is limited to several points. However some concepts used like UML extension mechanism but the main limitations are:

(i) Modern web applications that consist of UWA, RIA, SWA, and IWA, through selecting widely utilized features from each of them.
(ii) Adaptability for modern web application features especially adaptive model for IFML method to develop multi-web application features, this model will be a novel model for IFML as recent WEM.
(iii) Extension of metamodels that define a new adaptive model for IFML especially extension the core models.
(iv) MockupDD approach for agility IFML method in the process development lifecycle. The MockupDD used because it provided an agile environment.
(v) IFML Editor tool for implementing the new IFML method, also some assistant tools such as Balsamiq, and computer languages like AJAX.
(vi) Usability Metrics to measure the quality of the new WEMs are; learnability, efficiency, memorability, errors, satisfaction, and easy to use.

1.6 Significance of Research

Findings from this research contribute to the new WEM through extension and improvement current method that called IFML. This research proposes a new IFML method to develop multi-web applications in the agile lifecycle. Three main significances could be addressed in proposing the new IFML that are adaptability, agility, and usability. The first importance of the new IFML is developing all features from modern web applications through an adaptive model, and this model has the capability for adding new web application features when it will be defined in the future. The second importance is supporting whole lifecycle phases of web engineering process, and the new method covers lifecycle through agility by using MockupDD, will be a single method to develop web application in the whole lifecycle phases. The third finding is usability. The new IFML can support multi-web application feature with cover lifecycle phases; these supports leased to the new IFML become to a more usable method from academics and developers.

1.7 Thesis Layout

This thesis is organized as follows:

Chapter 2: Literature Review describes the findings of the review on the literature of existing works. The literature review consists of two steps. The first step is a systematic mapping study covering works on MDWE. The second step reviews the literature concerning WEMs, adaptability, agility for web engineering, case tools, and usability evaluation.

Chapter 3: This chapter details the research methodology and instrumentation used in the research, characterization of scenario and case study, and elaboration of case tools.

Chapter 4: This chapter analyzes modern web application features, followed by extracting these features based on WEMs' requirements. Further, the chapter elaborates the design of case studies by using current IFML to present the capability of IFML in the process of developing multi-web applications.

Chapter 5: This chapter defines a new adaptive model for IFML that is used to develop multi-web application features. The extension of IFML metamodel allows the new method to be realized through extending existing UML notations.

Chapter 6: This chapter solves lifecycle issue in MockupDD, which is helpful for IFML lifecycle. Here, MockupDD offers scrum methodology in the process of the development lifecycle.

Chapter 7: In this chapter, the integration between a new adaptive model for IFML and agile process for IFML is proposed. This integration becomes a determining factor that is viewed to increase the usability of the new IFML.

Chapter 8: This chapter elaborates the usability evaluation of the new IFML. The usability evaluation utilizes a new framework, which is used to assess the usability of the proposed WEM. This usability evaluation uses to measure the quality of the new IFML upon the addition of an adaptive model and agility consideration.

Chapter 9: This chapter concludes the thesis, and summarized the findings, resolved issues, and future works.

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