NEW ASPECT OF CODE AUTOMATION FOR WEB APPLICATION FRAMEWORK

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DEDICATION

This research is dedicated to positive change

in a world full of opportunity

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ABSTRACT

The adoption of Web Application Framework in Web Application (WA) development has superseded the conventional development method due to the productive Create Read Update Delete (CRUD) operation, Model View Controller (MVC) architecture and rapid application development method. The dominant explanation for this development technique is the CRUD operation ability. The CRUD operation is a tool that creates WA's core components (user interface and functions) for creating, reading, updating, and deleting content. Previous research has generally depended on integrating external features after the CRUD operation to improve the core components. However, it has been unable to detangle the automation challenges in feature integration to increase the CRUD operation's productivity. The absence of integrated WA important aspects such as search, authentication, reporting, audit trail and other features require the developer to spend more time on manual integration due to the coding process and testing. As a result, this research aims to improve CRUD operation effectiveness and efficiency by including the identified WA important aspects in it. In this context, the CRUD operation's effectiveness and efficiency are defined as a code automation's ability to integrate multi-feature functions and deliver comprehensive WA components with the code automation. Based on the design science research paradigm, the Multivocal Literature Review (MLR) was conducted to investigate the WA's important aspects. Twelve WA's important aspects were identified using the MLR to formulate the Restructured-CRUD (Re-CRUD). The process of integrating WA's important aspects with Re-CRUD was divided into small incremental builds using the incremental and iterative methodology. The Desmet Feature Analysis and System Usability Scale (SUS) questionnaires were utilised to assess the effectiveness and efficiency of Re-CRUD. A case study based on an electronic document management system was developed using Re-CRUD as a prototype for Desmet Feature Analysis and validated by eight experts using SUS. The Desmet Feature Analysis result revealed that the Re-CRUD feature set overall weighting score was 88 percent compared to the other CRUD generator with a lower score. According to SUS results, most experts agree that Re-CRUD is effective and efficient for WA development. Both analyses concluded that Re-CRUD is justified and beneficial for WA's development.

ABSTRAK

Penggunaan Rangka Kerja Aplikasi Web (WA) dalam pembangunan WA telah menggantikan kaedah pembangunan konvensional kerana operasi Cipta, Baca, Kemaskini Padam (CRUD) yang lebih produktif, berserta kaedah Model Paparan Kawalan (MVC) dan pembangunan aplikasi pantas. Penjelasan yang dominan untuk penggunaan teknik pembangunan ini ialah keupayaan operasi CRUD. Operasi CRUD ialah kaedah yang digunakan untuk mencipta komponen teras WA (antara muka dan fungsi pengguna) untuk mencipta, membaca, mengemas kini dan memadam kandungan. Penyelidikan terdahulu secara amnya memerlukan integrasi fungsi luaran WA berlaku selepas selesai operasi CRUD untuk menambah baik komponen teras. Walau bagaimanapun, ia tidak dapat menyelesaikan cabaran automasi dalam integrasi fungsi tambahan untuk meningkatkan produktiviti operasi CRUD. Ketiadaan aspek penting WA bersepadu seperti carian, pengesahan, pelaporan, jejak audit dan fungsifungsi lain memerlukan pembangun WA menghabiskan lebih banyak masa untuk mengintegrasi fungsi tambahan secara manual disebabkan proses pengekodan serta ujian. Penyelidikan ini adalah bertujuan untuk meningkatkan keberkesanan dan kecekapan CRUD dengan memasukkan aspek penting WA yang dikenal pasti dalam operasi CRUD. Dalam konteks ini, keberkesanan dan kecekapan operasi CRUD ditakrifkan sebagai keupayaan automasi penjanaan kod untuk integrasi pelbagai fungsi dan menyediakan komponen WA yang lebih komprehensif. Berdasarkan paradigma penyelidikan sains reka bentuk, Sorotan Kajian Multivokal (MLR) telah dijalankan untuk mengenal pasti aspek penting WA. Dua belas aspek penting bagi WA telah dikenal pasti menggunakan MLR untuk merumus Penstrukturan-CRUD (Re-CRUD). Proses integrasi aspek penting dibahagikan kepada binaan tambahan kecil menggunakan metodologi tambahan dan berulang. Soalan Analisis Ciri Desmet dan Skala Kebolehgunaan Sistem (SUS) digunakan untuk menilai keberkesanan dan kecekapan Re-CRUD. Kajian kes berdasarkan sistem pengurusan dokumen elektronik dibangunkan dengan menggunakan Re-CRUD sebagai prototaip untuk analisa Desmet dan telah disahkan oleh lapan pakar menggunakan SUS. Keputusan analisa Desmet menunjukkan bahawa skor pemberat keseluruhan Re-CRUD ialah 88 peratus berbanding penjana CRUD yang lain dengan skor yang lebih rendah. Menurut keputusan SUS, majoriti pakar bersetuju bahawa Re-CRUD adalah berkesan dan cekap untuk pembangunan WA. Kedua-dua analisis menyimpulkan bahawa Re-CRUD adalah wajar dan bermanfaat untuk digunakan oleh pembangunan WA.

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LIST OF ABBREVIATIONS

| ACM | - | Association for Computing Machinery |
|----------|---|---|
| AIS | - | Association Information System |
| AJAX | - | Asynchronous JavaScript and XML |
| API | - | Application programming interface |
| AV | - | Audio Visual |
| CDN | - | Content Delivery Network |
| CF | - | Console Framework |
| CLI | - | Command Line Interface |
| CMS | - | Content Management System |
| CRUD | - | Create Read Update Delete |
| CRUD(SS) | - | Create-Read-Update-Delete-Search-Statistic |
| CSS | - | Cascading Style Sheet |
| CSV | - | Comma-separated values |
| DOI | - | Digital Object Identifier |
| DOM | - | Document Object Model |
| DRY | - | Don't Repeat Yourself |
| DSR | - | Design Science Research |
| EDMS | - | Electronic Document Management System |
| EP | - | Evolutionary Prototyping |
| ER | - | Electronic Records |
| FAQ | - | Frequently Asked Question |
| FIW | - | Feature Important Weightage |
| FSS | - | Feature Set Score |
| GPL | - | General Public License |
| HTML | - | HyperText Markup Language |
| HTTP | - | Hyper Text Transfer Protocol |
| I18n | - | Internationalisation |
| ID | - | Identifier |
| IDE | - | Integrated Development Environment |
| IEEE | - | Institute of Electrical and Electronics Engineers |

| IPC | - | Information Processing Cycle209 |
|-------|---|---------------------------------------|
| IR4.0 | - | Industrial Revolution 4 |
| IS | - | Information System |
| IT | - | Information Technology |
| JIS | - | Judgement and Interpretation Scale |
| JSON | - | JavaScript Object Notation |
| L10n | - | Localization |
| LESS | - | Leaner Style Sheets |
| LGPL | - | Lesser General Public License |
| MDE | - | Model-Driven Engineering |
| MFSS | - | Max-Feature Set Score |
| MIT | - | Massachusetts Institute of Technology |
| MLR | - | Multivocal Literature Review |
| MS | - | Microsoft |
| MVC | - | Model View Controller |
| OOP | - | Object-Oriented Programming |
| ORM | - | Object Relational Mapping |
| OS | - | Operating System |
| PDF | - | Portable Document Format |
| PHP | - | Pre-Hypertext Processor |
| PRG | - | POST-redirect-GET |
| PS | - | Primary Study |
| PSR | - | PHP Standard Recommendations |
| QA | - | Quality Assessment |
| QR | - | Quick Response |
| RAD | - | Rapid Application Development |
| RBAC | - | Role-based Access Control |
| REST | - | Representational state transfer |
| RO | - | Research Objective |
| RQ | - | Research Question |
| SCRUD | - | Search Create Read Update Delete |
| SDLC | - | System Development Life Cycle |
| SEO | - | Search Engine Optimization |

| SERPs | - | Search Engine Results Pages |
|---------|---|------------------------------|
| SFWS | - | Sub-Feature Weighting Score |
| SLR | - | Systematic Literature Review |
| SQL | - | Structured Query Language |
| SUS | - | System Usability Scale |
| UI | - | User Interface |
| URL | - | Uniform Resource Locator |
| UX | - | User Experience |
| V&V | - | Verification and Validation |
| VS | - | Visual Studio |
| WA | - | Web Application |
| WAF | - | Web Application Framework |
| WOS | - | Web of Science |
| WWW | - | World Wide Web |
| WYSIWYG | - | What You See Is What You Get |
| XML | - | Extensible Markup Language |

CHAPTER 1

INTRODUCTION

1.1 Overview

In recent years, the worldwide expansion of internet technologies and the World Wide Web (WWW) has witnessed a booming rise in popularity and adoption of Web Application (WA) that has replaced the traditional application. The WA is more practical, practises centralised processing and can be easily access through a web browser. Most operating systems (desktop or mobile) have integrated web browsers as standard features. WA refers to any program accessible over a web browser using a network connection (internet or intranet) through HyperText Transfer Protocol (HTTP). In the early stages of the WA era, all development was manually coded that required lots of coding writing and a longer time frame for the development process. There was also a risk of programmers exhibiting a pattern of erroneous coding practices or behaviour, which led to vulnerable code without a proper Integrated Development Environment (IDE) and code automation to facilitate programmers during the coding writing (Curie *et al.*, 2019).

With the advancement of technologies, the software development paradigm has also changed from third-generation programming language to Model-Driven Engineering (MDE) to comply with the complexity of WA. The MDE aims to achieve a more complex level of abstraction than common practice and advocates the use of models as the most important components in the web application development process (Brambilla *et al.*, 2017; Zolotas *et al.*, 2017). A particular segment of MDE technologies for WA development is the Web Application Framework (WAF) eg: Laravel, CakePHP, FuelPHP and others which has recently gained particular importance, as WAF has facilitated the development of wide varieties of WA. Most WAF is designed based on the Model View Controller (MVC) architecture (CodeIgniter Foundation, 2019; Laaziri, Benmoussa, Khoulji and Kerkeb, 2019; Laravel, 2019; Sinha, 2019; Symfony, 2019; CakePHP, 2020). The MVC architecture was originally developed for desktop applications, but it has also been adopted by WAF due to the architecture's accord and practicality. Besides, other components like the source code, user interface (UI) and validation can be automatically generated from those models using the model transformation mechanism.

The Industrial Revolution 4 (IR4.0) has changed the WA and information management spectrum due to the high demand for information processing, manipulating, analysis and content management. Most organisations depend highly on the WA to access, process, manipulate, collaborate, and distribute information to gain a competitive advantage (Barnes et al., 2003; Altamony et al., 2012; Aburub, 2015; Susanto and Meiryani, 2019). Adopting WA in job task and organization gives advantages to the processes mentioned above and promotes cost-saving on human capital, time, and financial resources. WA development is easier with WAF using the MVC architecture as it is more practical than the conventional development method (McArthur, 2008; Pitt, 2012; Olanrewaju et al., 2015; Miles, 2016; Kelly, 2019). MVC architecture makes the development process more manageable, and it is also well maintained because it separates the WA development into a few fragments; i) Model - provides data maintenance and associate logic to the view; ii) View - renders content to the end-user and relay user command to the controller; iii) Controller - request handler which renders command and provides an appropriate response. Many WAFs currently offer Create Read Update Delete (CRUD) operation using a built-in console framework as the generator or a third-party application.

1.2 Background of Study

The rapid development of internet technologies, especially for WA indicates a higher demand for the reliability, flexibility, scalability, security, and maintainability of coding methodology. Today, WA has overruled the traditional Information System (IS) due to its flexibility of access, centralised management, faster, less dependency and ease of maintenance (Murugesan *et al.*, 2001; Miles, 2016; Prokofyeva and Boltunova, 2016). The growth of mobile technologies has also significantly affected

WA adoption because mobile devices allow WA to be portable and accessible from anywhere at any time. Current WA architecture is powered by a web-based engine that promotes centralised systems and data management. The web-based architecture is gaining attention and popularity compared to conventional architecture that requires end-users to install the application system into their system. A web browser has the advantage of cross-platform compatibility for common devices (computer, laptop, tablet, and phone) that enables access to the web-based application without installation. WA has become an important productivity and communication tool due to the exponential growth in Information Technology (IT) (Oluwafunmibi Seun Idowu, 2019).

Adopting the MVC architecture in WA development using WAF enables entry-level developers to create a WA rapidly (Miles, 2016). Although many WAFs are available for download, it is critical to ensure the framework that is the most suitable and can maintain in the long term. The WAF's objective is not simply to provide utilities for WA development but to make WA development as easy as possible (Massimo Di Pierro, 2011). WAF acts as a platform for Rapid Application Development (RAD), in which it promotes the CRUD operation, code re-use and universality. The introduction of WAF has modernized the development of WA by promoting better coding management using MVC architecture, CRUD operation, rapid development concept, libraries, templates, session management and code reuse (Pitt, 2012; Miles, 2016; Prokofyeva and Boltunova, 2016). Using CRUD operation in WA development enables less-experienced developers to rapidly generate the WA's skeleton (Miles, 2016).

Technically the CRUD operation in WAF is limited to generating fundamental components and functions only, in which lack essential features like search, report, authentication, authorization, internationalisation and others that should be available in WA (Das and Saikia, 2016; Dāsa, 2016; Rodriguez-Echeverria *et al.*, 2018; Onesinus, 2019). The improvement of the WA features needs to be executed after the CRUD operation which involves integrating other necessary features. Integrating the other WA features requires more technical skills, longer time, and more testing, which could impact the entire development process.

1.3 Problem Statement

The CRUD framework enables the developer to generate the fundamental files and codes to form a WA skeleton. Based on the database table configuration, it parses the database schema and generates code for each table based on the MVC pattern (Giatsoglou et al., 2010). Most developers used the CRUD framework to speed up the development process. Although it boosts the development process, the traditional CRUD generator only generates the fundamental functions that still pose problems like inadequacy to deal with the form features and others that concern authentication, search, file management, and others. (Hu et al., 2008; Das and Saikia, 2016; Dāsa, 2016; Rodriguez-Echeverria et al., 2018; Onesinus, 2019). A standalone CRUD framework could not satisfy the development of decent and complex WA since it lacks common modern WA features to support the functions such as authentication, authorization, files management, search, internationalization, form features, report, logging and others (Dasa, 2016; Rodriguez-Echeverria et al., 2018; Onesinus, 2019). Further enhancement and manual code modification are required to improvise the halfbaked CRUD output, especially in integrating the time-consuming features, as they comprise repetitive coding for each CRUD output (Rodriguez-Echeverria et al., 2018).

Based on previous studies, various solutions have been proposed, for example, using a plugin and third-party components. However, most of the solutions solved the problem separately, which were not integrated solutions covering all aspects of features required in WA. Despite offering a full-stack solution, many of the solutions are complex and have a higher learning curve to adopt the solution, especially those required and use other dependency components. As a result of the lack of features in the CRUD framework, developers need to go through a major modification to integrate the necessary features to enhance the CRUD output. The integration requires more time as developers need to identify the required features and read the documentation and specifications. They also need to test the compatibility of the features before executing the integration process, which can affect the development's productivity.

Developers are facing a problem integrating the plugin, leading to a vulnerable application due to the complexity of coding integration (Rodriguez-Echeverria *et al.*,

2018). Hence, the concept of using a framework is to build rapidly, but if the plugin's integration requires more time, it partially beats the purpose of using the CRUD framework (Paolone *et al.*, 2020). There is also an argument that the CRUD operation is not yet a complete solution to developing the WA. Many redundant tasks, including repetitive code modification for feature integration after generating the CRUD (Rodriguez-Echeverria *et al.*, 2018). Coding the same routine code for WA features repeatedly takes a long time and increases development costs (Bandirmali, 2018).

In practice, additional feature integration in CRUD-generated WA is timeconsuming and requires understanding multiple programming languages since the features are written in different languages. It also requires significant code enhancement to include all necessary WA features. The features integration in CRUD for the aforementioned WA features and functions has not yet been clarified. Therefore, this research addresses the lack of features integration in the CRUD framework for WA development which needs further enhancement. Implementing the CRUD operations shows that the repetitive and recurrent tasks in WA development can be systematically automated using standard coding generation and a model-driven approach (Rodriguez-Echeverria *et al.*, 2019).

1.4 Research Questions

Based on the identified problem, the main research question is:

How to design and implement an effective CRUD operation with integrated important aspects for WA development?

To answer this question, the following supporting questions are raised:

- (a) What is the important aspect that should be emphasized in WA?
- (b) What is the effective method to integrate the WA important aspect into the CRUD framework?

- (c) How are these important aspects incorporated into CRUD framework?
- (d) How are these important aspects used to enhance the CRUD framework and WA features?

1.5 Research Objectives

Derive from the research questions, the main purpose of this study is to design and integrate the WA important aspects into CRUD operation. The following objectives have been identified to achieve the main purpose:

- (a) To investigate the important aspects that should be emphasized in WA.
- (b) To formulate an enhanced CRUD framework that integrates the WA important aspects.
- (c) To design and develop the prototype of the proposed CRUD framework.
- (d) To evaluate the effectiveness and efficiency of the developed CRUD framework through a series of WA development case studies.

1.6 Scope of the Study

This study focuses on enhancing the CRUD operation output with integrated WA important aspects. As described in the Software Engineering Body of Knowledge (SWEBOK) in Software Construction – Software Construction Fundamentals - Minimizing Complexity (Bourque and Fairley, 2014). In software construction, reduced complexity is achieved by emphasizing code creation that is simple and readable. It is accomplished using standards, modular design, and numerous other

techniques, including code and file creation automation. Re-CRUD enables the developer to construct the WA files and code through CLI instruction and makes WA development easier and faster with less complex codings. This study also contributes to code reuse and features extension as explained in Software Design - Software Structure and Architecture - Families of Programs and Frameworks (Bourque and Fairley, 2014). The MVC approach enables the reuse of software designs, and components to design families of programs, also known as software product lines. This can be done by identifying the commonalities among members of such families and by designing reusable and customizable components. In object-oriented programming, a key related notion is that of a framework: a partially completed software system that can be extended by appropriately instantiating specific extensions (such as plug-ins). Re-CRUD enables code reuse, extending the features and function of generated WA.

This study also focuses on the types of WAF console frameworks mainly targeted to generate the CRUD for WA development. Thus, it investigates and explores the WA important aspect that should be emphasized in the CRUD operation. It also focuses on integrating the important aspects into the console framework to enhance the CRUD output. Other possible supporting WA features such as mobile-friendly UI, navigation, and configurations can also be generated through CRUD operation. Within the objectives of the study, it will focus on the below aspects:

- (a) The features are limited to the web-based application that are useful for digital content management. There are numerous numbers of features that have been published on online repository, and some of them have similar functions.
- (b) The proposed console framework only includes the identified features and does not cover the unpublished features.
- (c) The CRUD output from the proposed console framework is limited to the integrated features only. However, the output follows the MVC architecture, and rapid application methodologies are applied in web application development.
- (d) The evaluation is regulated to assessing the effectiveness and efficiency of important aspects that have been integrated.

1.7 Significance of the Study

This study provides advantages to the industry and academia. In the WA development industry, developers gain benefits from the enhanced CRUD operation as it enables rapid prototyping development for WA by integrating the important and useful features to improve the generated WA functions. Besides, it also promotes complex code automation and reusable components. The integration can also reduce the risk of code errors due to manual integration and make it easier for developers to get an early view of the WA structure and logic. For the academic research community, this study provides a better understanding on how WA's important aspects and CRUD operation should be incorporated to provide a comprehensive solution for code automation in WA development. This is important as many studies have investigated how to make WA development easier and faster using the CRUD process (Das and Saikia, 2016; Onesinus, 2019; Rodriguez-Echeverria *et al.*, 2019).

1.8 Motivation

Currently, many CRUD generators are purposely used to generate the fundamental function for WA. Technically, CRUD generates basic WA routine code for all functions and defines how objects are related in WA. Although many developers have widely used the CRUD to develop the WA rapidly, it still lacks other important aspects or features for a WA to manage the digital data and content effectively, for example, searching, reporting, archiving and other features. Several problems with the current CRUD generator have been identified. The current CRUD solution would not be a complete solution for rapid WA development, where the developer must manually code the other fundamental features. These processes require more time due to the coding and testing procedure. In contrast, the Re-CRUD provides a comprehensive solution for generating the CRUD with integrated important features to enhance the ability of the WA to manage digital data and contents.

1.9 Organization of Chapters

The thesis is organised into six chapters. All chapters are interrelated to one another. Thus, the chapters should not be read in isolation. Chapters 1, 2 and 3 introduce the topic of research, provide the discussions on relevant literatures, and present the process of conducting the research. Besides general definitions, the WA important aspect has been identified using the Multivocal Literature Review (MLR) method. The WAF CRUD operation used for WA development is discussed in chapter 2. Chapter 3 presents the descriptions on the research methodology and research design. Chapter 4 provides the design and the development of the proposed solution. Chapter 5 presents the evaluation using feature analysis, and Chapter 6 provides the conclusion.

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