SELF-ADAPTIVE MOBILE WEB SERVICE DISCOVERY FRAMEWORK FOR DYNAMIC MOBILE ENVIRONMENT

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DEDICATION

"In the Name of Allah, the Most Beneficent, the Most Merciful"

To my beloved family and friends
Thanks for your immense love, your precious prayers, supports, and all that you have done for me. May the blessings of Allah be upon you now and always.

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All praise and gratitude are due to Allah the Almighty, for the strength that keeps me standing and for the hope that keeps me believing this thesis would be possible and rewarding. Peace and blessings are upon His Messenger, Muhammad (S.A.W).

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ABSTRACT

The advancement in mobile technologies has undoubtedly turned mobile web service (MWS) into a significant computing resource in a dynamic mobile environment (DME). The discovery is one of the critical stages in the MWS life cycle to identify the most relevant MWS for a particular task as per the request's context needs. While the traditional service discovery frameworks that assume the world is static with predetermined context are constrained in DME, the adaptive solutions show potential. Unfortunately, the effectiveness of these frameworks is plagued by three problems. Firstly, the coarse-grained MWS categorization approach that fails to deal with the proliferation of functionally similar MWS. Secondly, context models constricted by insufficient expressiveness and inadequate extensibility confound the difficulty in describing the DME, MWS, and the user's MWS needs. Thirdly, matchmaking requires manual adjustment and disregard context information that triggers self-adaptation, leading to the ineffective and inaccurate discovery of relevant MWS. Therefore, to address these challenges, a self-adaptive MWS discovery framework for DME comprises an enhanced MWS categorization approach, an extensible meta-context ontology model, and a self-adaptive MWS matchmaker is proposed. In this research, the MWS categorization is achieved by extracting the goals and tags from the functional description of MWS and then subsuming k-means in the modified negative selection algorithm (M-NSA) to create categories that contain similar MWS. The designing of meta-context ontology is conducted using the lightweight unified process for ontology building (UPON-Lite) in collaboration with the feature-oriented domain analysis (FODA). The self-adaptive MWS matchmaking is achieved by enabling the self-adaptive matchmaker to learn MWS relevance using a Modified-Negative Selection Algorithm (M-NSA) and retrieve the most relevant MWS based on the current context of the discovery. The MWS categorization approach was evaluated, and its impact on the effectiveness of the framework is assessed. The meta-context ontology was evaluated using case studies, and its impact on the service relevance learning was assessed. The proposed framework was evaluated using a case study and the ProgrammableWeb dataset. It exhibits significant improvements in terms of binary relevance, graded relevance, and statistical significance, with the highest average precision value of 0.9167. This study demonstrates that the proposed framework is accurate and effective for service-based application designers and other MWS clients.

ABSTRAK

Kemajuan dalam teknologi mudah alih sudah pasti menjadikan perkhidmatan web mudah alih (MWS) menjadi sumber pengkomputeran yang signifikan dalam persekitaran mudah alih yang dinamik (DME). Penemuan ini adalah salah satu tahap penting dalam kitaran hidup MWS untuk mengenal pasti MWS yang paling relevan untuk tugas tertentu mengikut keperluan konteks permintaan. Walaupun kerangka penemuan perkhidmatan tradisional yang menganggap dunia statik dengan konteks yang telah ditentukan dibatasi dalam DME, penyelesaian adaptif menunjukkan potensi. Malangnya, keberkesanan kerangka ini terganggu oleh tiga masalah. Pertama, pendekatan pengkategorian MWS kasar yang gagal menangani percambahan MWS yang mempunyai fungsi yang sama. Kedua, model konteks yang dibatasi oleh ekspresi yang tidak mencukupi dan kebolehpanjangan yang tidak mencukupi menyukarkan dalam memerihalkan DME, MWS, dan keperluan MWS pengguna. Ketiga, pemadanan memerlukan penyesuaian manual dan mengabaikan maklumat konteks yang memacukan penyesuaian diri, yang membawa kepada penemuan MWS yang relevan dan tidak tepat. Oleh itu, untuk menangani cabaran ini, kerangka penemuan MWS yang dapat disesuaikan untuk DME merangkumi pendekatan pengkategorian MWS yang disempurnakan, model ontologi meta-konteks yang dapat diperluas, dan pemadanan sesuai diri MWS diperkenalkan. Dalam penyelidikan ini, pengkategorian MWS dicapai dengan mengekstrak matlamat dan tanda dari penerangan fungsian MWS dan kemudian memasukkan k-mean dalam algoritma pemilihan negatif yang diubah (M-NSA) untuk membuat kategori yang mengandungi MWS yang serupa. Perancangan ontologi meta-konteks dilakukan dengan menggunakan proses penyatuan ringan untuk pembinaan ontologi (UPON-Lite) bekerjasama dengan analisis domain berorientasikan ciri (FODA). Pemadanan sesuai diri MWS dicapai dengan memungkinkan Pemadanan sesuai diri untuk belajar perkaitan MWS menggunakan Algoritma Pemilihan Modifikasi-Negatif (M-NSA) dan mengambil MWS yang paling relevan berdasarkan konteks penemuan semasa. Pendekatan pengkategorian MWS dinilai, dan kesannya terhadap keberkesanan kerangka dinilai. Ontologi meta-konteks dinilai menggunakan kajian kes, dan kesannya terhadap pembelajaran relevansi perkhidmatan dinilai. Kerangka kerja yang dicadangkan dinilai menggunakan kajian kes dan set data *ProgrammableWeb*. Ia menunjukkan peningkatan yang signifikan dari segi relevansi binari, relevansi dinilai, dan kepentingan statistik, dengan nilai ketepatan purata tertinggi 0.9167. Kajian ini menunjukkan bahawa kerangka kerja yang dicadangkan tepat dan berkesan untuk pereka aplikasi berasaskan perkhidmatan dan pelanggan MWS lain.

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LIST OF ABBREVIATIONS

AAM	-	Average Aggregate Method
BPEL	-	Business Process Execution Language
BPM	-	Business Performance Management
CBR	-	Case-Based Reasoning
CORBA	-	Common Object Request Broker Architecture
CSO	-	Cat Swarm Optimization
CSV	-	Command Separated Value
CVC	-	Computing Value Chain
DCOM	-	Distributed Component Object Model
EU	-	European Union
GA	-	Genetic Algorithm
HIN	-	Heterogeneous Information Network
HTML	-	Hypertext Mark-up Language
HTTP	-	HyperText Transfer Protocol
IR	-	Information Retrieval
JSON	-	JavaScript Object Notation
LDA	-	Latent Dirichlet allocation
M-NSA	-	Modified Negative Selection Algorithm
MWS	-	Mobile Web Service
MH	-	Mobile Host
NFP	-	Non-Functional Property
NSA	-	Negative Selection Algorithm
OWL	-	Ontology Web Language
OWL-S	-	Ontology Web Language for Services
PICO	-	Population, Intervention, Comparison, Outcome
pLSA	-	Probabilistic Latent Semantic Analysis
PSO	-	Particle Swarm Optimization
QoWS	-	Quality of Web Service
RAML	-	RESTful API Modelling Language
RDF	-	Resource Description Framework

RSS	-	Really Simple Syndication
REST	-	Representational State Transfer
SAWSDL	-	Semantic Annotation for WSDL
SA-REST	-	Semantic Annotation of REST
SIMCR	-	Similarity Integrating Multiple Conceptual Relationships
SME2	-	Semantic Web Service Matchmaker Evaluation Environment
SOA	-	Service Oriented Architecture
SOAP	-	Simple Object Access Protocol
SVM	-	Support Vector Machine
TF-IDF		Term Frequency–Inverse Document Frequency
UDDI	-	Universal Description Discovery and Integration
W3C	-	World Wide Web Consortium
WADL	-	Web Application Description Language
WDSL	-	Web Services Description/Definition Language
WS*	-	Web Service Standards
WSDL-S	-	Web Service Description Language- Semantics
WSFL	-	Web Services Flow Language
WSMO	-	Web Service Modelling Ontology
WS-I	-	Web Services Interoperability
XML	-	Extensible Mark-up Language

LIST OF SYMBOLS

C_0	-	Coverage
D_{max}	-	Diameter
E_c	-	Estimated Coverage
U	-	Uncovered Regions
t	-	Maximum Age Detector
τ	-	Threshold
r_s	-	Radius

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CHAPTER 1

INTRODUCTION

1.1 Overview

Mobile Web Service (MWS) discovery is one of the critical stages in the web service life cycle: publishing, locating or discovery, selection, composition, and invocation (Fielding, 2000; Alonso et al., 2004; Saadon and Mohamad, 2015). The discovery is the act of matchmaking between the advertised MWS by the service publisher and the requested MWS to identify the most relevant web service for a particular task in accordance with the quality and context needs of the service request (Elgazzar et al., 2014; Ruta et al., 2015). The current web service technologies have been extended to mobile web services (MWS) due to the recent incarnation of the Internet of Things (IoT) technologies and mobile devices' advancement. The expectation that mobile internet adoption will revolutionize the broader digital ecosystem. The possibility of mobile devices becoming the primary tool used in accessing the internet is now a reality as the number of users accessing mobile services goes beyond 5 billion in 2017 (Sivakumaran and Iacopino, 2018). MWS is a lightweight subset of conventional web services. It requires adaptable protocols, RESTful description, smaller message formats suitable for deployment in resource-constrained devices in a dynamic mobile environment (DME) (Elgazzar et al., 2014; Scioscia et al., 2014; Ruta et al., 2015).

The mobile web service discovery framework provides a foundation for service-based application designers and other MWS clients to discover MWS for a particular task. It consists of three distinct parts: MWS provisioning, MWS request, and MWS matchmaking (Cheniki *et al.*, 2016). The MWS request describes the user's needs to obtain the most relevant MWS for a particular task. The MWS provisioning part is responsible for advertising the availability of MWS in a local service directory by individual MWS providers. The matchmaking part is responsible for determining

the degree of match between the advertised MWS and the requested MWS to find the most relevant web service for a particular task. The matchmaking techniques are usually classified into four categories based on the underlying algorithm used. This includes logic-based, syntactic, and hybrid (Dong et al., 2013; Gmati et al., 2018). Additionally, Klusch et al. (2016) recognize a new category of matchmaking technique called adaptive matchmaking.

The context manager is one of the components of the MWS matchmaking responsible for monitoring, collecting, organizing, and composing context information for matchmaking and ranking of MWS. Context and quality of web service are the distinguishable features among similar services (Bouguettaya *et al.*, 2017). Context is any information that can be used to characterize an entity's situation (e.g. location, device status, connectivity) that is considered relevant to the interaction between a user and an application inclusively (Abowd et al. Context-awareness is a key element that provides intelligence to the MWS discovery. Given the benefits offered by ontologies such as explicit knowledge representation, knowledge sharing, knowledge reuse, expressive power, reasoning and inference, detection of inconsistencies, simplifying functional complexities, etc. (Cabrera *et al.*, 2017), it is usually employed to represent the context in a dynamic mobile environment (DME).

The provisioning of MWS is continuous as services can be offered by small providers, including individuals, leading to proliferation and a high influx of similar MWS. This results in a huge search space that affects the discovery's effectiveness (Zhang *et al.*, 2018). To deal with these complications, MWS categorization approaches such as (Cao *et al.*, 2013, 2017; Jiang *et al.*, 2017) are proposed. The MWS categorization uses clustering or classification methods to distribute MWS into groups such that the affinity or closeness between MWS inside one group is high and the affinity or closeness between dissimilar groups is low.

The discovery of MWS normally takes place in a dynamic mobile environment (DME); an environment that consists of heterogeneous mobile devices operated by numerous classes of users in highly mutable settings (Mezni and Sellami, 2016; Bobek and Nalepa, 2017; Barakat *et al.*, 2018; Verma and Srivastava, 2018b). This makes it

almost impossible to have an exhaustive model that is applicable in all MWS discovery scenarios. The renewed interest in lightweight and autonomous solutions renders the usual matchmaking techniques difficult to apply in DME (Xiong *et al.*, 2018). As such, a self-adaptive MWS discovery framework that assesses and defines alternative solutions at whatever point the assessment demonstrates that the service has failed according to its functional and quality values, and/or the service does not fit the required context is gaining popularity in solving MWS discovery problems in DME (Vinh, 2016). Usually, the solution to such problems exists in approximate or exhaustive methods (Sangers *et al.*, 2013). Metaheuristic algorithms such as the Negative Selection algorithm (NSA) are special form of approximate algorithms adopted to solve numerous web service discovery and composition problems (Zhao et al., 2014, 2019). There are multiple directions in which research on MWS discovery is gradually developing.

1.2 Problem Background

Web service has been at the core of profound research for more than a decade. The task of discovering service according to quality and context attributes suitable for a particular user's needs is complicated (Bouguettaya *et al.*, 2017). The fourth industrial revolution(4IR) brings about disruptive technologies such as the Internet of Things (IoT) that use sensors to generate a formidable amount of data which can be used for making decisions, and artificial intelligence (AI) that can create extremely complex, as well as accurate data models in seconds. The growing edge of wireless networks due to widespread deployment of 4G and 5G technologies increases the flexibility and efficiency in providing MWS, with new services offered rapidly to satisfy the huge number of mobile users (Anderson *et al.*, 2009; Sivakumaran and Iacopino, 2018).

The procedure of MWS discovery in a dynamic mobile environment presents its own unique set of challenges. This is because of the proliferation of MWS with similar functionality described using different description languages, the explosion of users accessing mobile services using diverse of mobile devices, coupled with the persistent changes in a DME and lack of matchmaking technique that is equipped with

the ability to adapt leads to challenges in the task of discovering MWS. Subsequently, a significant part of the research endeavours has concentrated on MWS discovery to deal with some of the challenges (Yachir et al., 2015). Many solutions are proposed to handle different challenges.

Sellami *et al.*, (2013); Lin *et al.*, (2014); Barod *et al.*, (2016); Kotekar and Kamath, (2016); Abid *et al.*, (2017); Corbellini *et al.*, (2017) uses enhanced edge counting similarity measure and graph theory, topological metrics, pragmatics to assess service similarity and structuring the set of available services as a hierarchy of classes to deal with complications caused by the proliferation of functionally similar MWS which result in huge search space. However, these approaches suffer from a lack of consideration for the large collection of non-functional user constraints that must be satisfied by the discovery framework and are limited to a few Web Service Description Languages (WSDL). Moreover, the performance of meta-heuristics clustering algorithms used in (Pop *et al.*, 2010; Nagy *et al.*, 2011; Kotekar and Kamath, 2016, 2018; Spezzano, 2016) is sometimes unpredictable. The similarity measure such as Term Frequency–Inverse Document Frequency (TF–IDF), Euclidean distance, and Cosine similarity may lead to loss of semantic information due to heterogeneity of service publishers. Besides, the balance between optimal solution and acceptable execution time is assessed only to a very limited extent.

To bring rich awareness of the consumer's context in the MWS discovery, (Van Der Westhuizen and Coetzee, 2013; Furno and Zimeo, 2014; Viktoratos et al., 2014; Ahmed et al., 2015; Cherif et al., 2016) compute the weight of candidate services to a specific aggregated context. However, these approaches provide a domain-dependent class of context and fail to sufficiently defined the parts that make up the model. In addition, the predefined contexts used in these approaches affect its applicability in DME as it is hard to foresee all the conceivable circumstances emerging in a DME (Cherif et al., 2016). The work in Truong and Dustdar, (2009); Cabrera *et al.*, (2017) suggest the need to improve distributed context management techniques that use ontology to model context information for proper reasoning due to the complex nature of DME and persistent context update.

Narock *et al.*, (2014); El-Kafrawy *et al.*, (2015); Njima *et al.*, (2015); Muthuraman and Venkatesan, (2016); Ben Lamine *et al.*, 2017) combine various trust sources such as provenance information (Narock et al., 2014), collaborative filtering (Lin et al., 2014) and assesses the integrity of ratings, the reputation of service publishers and modelled the quality of web service (QoWS) in a trust-based web services discovery, in addition to a multi-level filtering process that reduces the complexity of the discovery. However, these approaches do not have the appropriate bootstrapping mechanism and depend solely on users' reviews without a proper mechanism for authenticating the credibility ratings. Furthermore, there may not be sufficient and qualitative user reviews to determine the exact QoWS values accurately. According to Bagtharia and Bohra, (2016), many approaches allocate an arbitrary QoWS value to be used in web service discovery, while Sambasivam et al. (2015) try to mitigate the problem of unnormalized QoWS. However, collaborative filtering requires the profiling of every query and data storage. The trade-offs between the QoWS parameters and the required computational resources are still insufficiently explored in these approaches apart from the shallow consideration of very few QoWS parameters.

In an effort to improve the MWS discovery framework, many significant contributions such as Elgazzar *et al.* (2014); Saadon and Mohamad (2015); Stavropoulos *et al.* (2016); Cheng *et al.* (2017); Guermah *et al.* (2018); Zhang *et al.*, (2018) are recorded that mainly focus on overcoming the complexity of logic-based service discovery in a resource-constrained device and resolve the inaccuracy of keyword-based service discovery. Zhang et al., (2018) recently proposed a keyword-based MWS discovery approach that discovers services based on the TF-IDF. The Cosine similarities between services and the request are calculated after which service discovery result is generated based on the similarities. However, the similarity measure used in keyword-based service discovery can only give an estimation of similarity between request and service after extensive refinement. It introduce ambiguation since it's based on TF-IDF, and lack accuracy due to the high number of false-positive (FP/F+ve) and the false negative (FN/F-ve) in matchmaking result (Stavropoulos *et al.*, 2016).

Contemporary self-adaptive frameworks include neural collaborative filtering (He *et al.*, 2017) and deep hybrid collaborative filtering (Xiong *et al.*, 2018) in which a deep neural network is used to capture the non-linear relationship between services, and the pointwise loss function is used to transform the discovery task into a regression or classification problem. Similarly, an adaptation of Probabilistic Latent Semantic Analysis (pLSA) in which the service attributes are modelled as a Heterogeneous Information Network (HIN) and Latent Dirichlet Allocation (LDA) is used to capture the underlying semantics of services and queries are proposed (Tian, Wang, *et al.*, 2019; Tian, Zhao, *et al.*, 2019; Xie *et al.*, 2019). However, the LDA-based approach is less effective as it can only capture fewer semantically consistent topics without the aid of word embedding or other query expansion strategies.

The existing machine learning-based techniques are the most promising; unfortunately, these techniques are mostly constricted by a design-time adaption strategy that requires recreation and retraining of the aggregation model after feedback collection over a period of time (when the model became obsolete). There is a clear lack of a reinforced learning approach that can make use of feedback information to provide more relevant MWS at runtime. Moreover, the high sparsity of the interaction matrix in Relational Topic Model With Factorization Machines (MTR-FM) hinders the accurate classification of MWS, while retraining a model from scratch is a very costly process (Klusch and Kapahnke, 2012). A significant number of machine learning-based techniques are based on the binary classification that demands an undesirable compromise between partial scores, which may lead to ineffectiveness and inaccuracy in discovery results. Furthermore, the extensive processing and continuous loop necessary to attain better results may lead to inefficiency discovery in DME.

Even though the recent attention given to self-adaptive MWS discovery is never in doubt, the researcher's focus is mainly on web service composition which depends on the ability of the discovery algorithm to identify the appropriate MWS especially in DME. The impact of self-adaptation at composition level can be considered belated as it is almost impossible for service providers to take note of ever-changing contexts at which the service can be executed (Wang and Tang, 2014). Some of the self-adaptive approaches (Ke and Huang, 2012; Win *et al.*, 2019) can lead to an

infinite loop. Therefore, the adaptation procedures utilized in these approaches may hinder other anticipated objectives of matchmaking in DME (such as efficient use of resources). In summary, the major drawbacks found in the literature are:

i. The limited accuracy of MWS categorization approaches that deal with huge search space due to the proliferation of functionally similar MWS can be improved to tackle the discovery of irrelevant MWS in DME.
ii. The context models that deal with the heterogeneous context knowledge which describes the DME, MWS, and the user's MWS needs and triggers adaptation are inexpressive and slightly fragmented.
iii. The MWS matchmakers require manual adjustment and disregard context information that triggers self-adaptation, leading to the inaccurate or ineffective discovery of relevant MWS in DME.

Given that the self-adaptive matchmaking defends on consistent and complete structure of the context knowledge (Cabrera et al., 2017), confine search space to cater for a resource-constrained mobile device (which is not the case presently) so as to provide accurate and effective discovery results. Thus, to improve the self-adaptive MWS discovery framework's effectiveness, there is a need to consider improving the accuracy and effectiveness of the search space reduction approach, context model, and the self-adaptive matchmaking algorithm. Figure 1.1 depicts the scenario leading to the problems and the anticipated solutions.

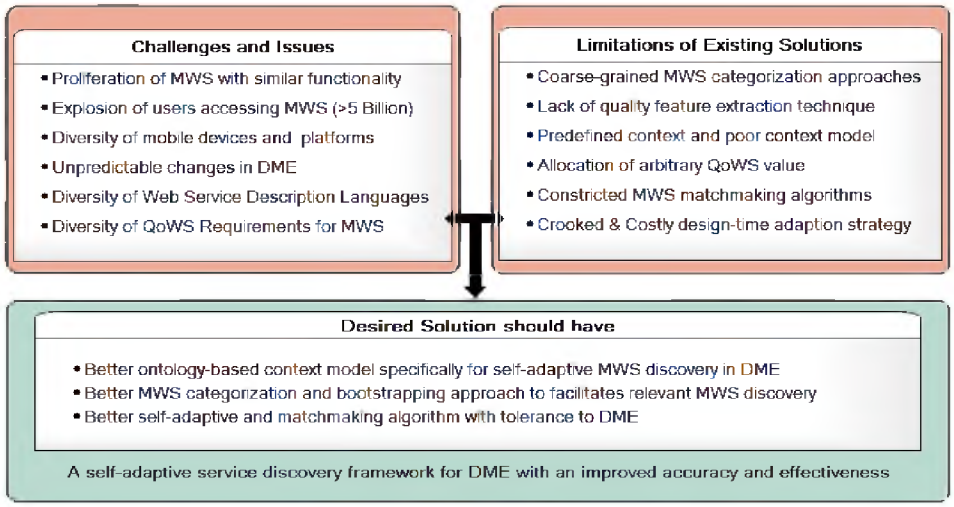

Figure 1.1 Scenario leading to the problems

1.3 Motivation of Study

The factors that motivate this research are fourfold. Firstly, mobile internet adoption is expected to revolutionize the broader digital ecosystem as the number of users accessing MWS goes beyond 5 billion in 2017 (Sivakumaran and Iacopino, 2018). The possibility of mobile devices becoming the primary tool used in accessing the internet by the year 2020 have been predicted by (Anderson *et al.*, 2009).

Secondly, the past decade has seen the rapid development of web services and the persistence storm of the internet, open protocols, and mobile devices' advancement have led to a renewed interest in web service discovery. Prior research such as Cao *et al.*, (2017); Kotekar & Kamath, (2018) emphasizes the importance and the need for a better approach in minimizing the search space through categorization to facilitate relevant MWS discovery in DME despite the large collection of web services coupled with other constraints that must be satisfied by the discovery framework.

Thirdly, MWS is discovered in a dynamic environment with restricted resources, which not only requires context and quality awareness due to in-part variability in context and quality of service but also a deeper management model for proper interpretation, integration, and monitoring. Cherif et al. (2016); Cabrera *et al.* (2017); Sambasivam *et al.* (2018); Tripathy and Tripathy (2018) suggest the need for improvement of distributed context and QoWS management model to devise requirements that are applicable to self-adaptive service discovery in DME.

Fourthly, the complexity of the matchmaking algorithm and the DME requires a self-adaptive approach that makes adjustments per the information obtained from the context model, define alternative solutions to withdraw unavailable service, when a service is predicted to be failed according to its quality values, and/or the service does not fit the required context (Vargas-Santiago *et al.*, 2018). The self-adaptive matchmaking initiatives proposed by Mezni and Sellami (2016); Athanasopoulos, (2017); Win *et al.* (2019) suggest that the use of a self-adaptive MWS discovery in DME is still in its infancy. This is the main idea that inspires the current research to propose the self-adaptive MWS discovery framework in DME.

1.4 Problem Statement

Mobile web services are much different from conventional web services. It requires adaptable protocols, RESTful description, smaller message formats suitable for deployment in resource-constrained devices in a dynamic mobile environment (DME). The task of discovering service according to quality and context attributes suitable for a particular user's needs is complicated. This is due to the use of traditional matchmaking techniques that are constrained by the specific web service description language, the proliferation of MWS with similar functionality, coupled with the persistent changes in a dynamic mobile environment (DME), limited context parameters with the allocation of predefined or arbitrary values and lack of matchmaking technique that is equipped with the ability to adapt. Different components of the MWS discovery framework contribute to the challenges in the task of discovering MWS. Three problems plague the accuracy and effectiveness of the MWS discovery framework. Firstly, coarse-grained and inaccurate MWS categorization approaches that failed to deal with the proliferation of MWS. Secondly, context models used in organizing large, heterogeneous context knowledge are constricted by insufficient expressiveness, inadequate extensibility, and slight fragmented, which confound the difficulty in describing the DME, MWS, and the user's MWS needs. Thirdly, matchmaker requires manual adjustment and fails to deal with the unpredictable changes in DME due to the constricted & ineffective matchmaking algorithm, crooked and costly design-time adaptation, which leads to ineffectiveness and inaccuracy in the discovery of relevant MWS. Hence, to realize the full potential of the self-adaptive MWS discovery framework, an improvement is required. As such, the main research question of this study can be specified as:

"How can the accuracy and effectiveness of the self-adaptive MWS discovery framework be increased in a dynamic mobile environment?"

In order to answer the main research question, five (5) sub-research questions are provided:

i. To what degree do the existing frameworks address the challenges in web service discovery? Why are the existing frameworks inaccurate and ineffective in MWS discovery?
ii. Why the huge search space in web service discovery? How to accurately categorize MWS, thus minimizing the search space and facilitating relevant web service discovery?
iii. How to provide an expressive and extendable context model that can manage and organize the heterogeneous context information in the self-adaptive MWS discovery framework?
iv. How to design a self-adaptive mobile web service matchmaker with improved accuracy and effectiveness? What are the suitable components for the self-adaptive mobile web service matchmaker?
v. How to integrate and evaluate the self-adaptive mobile web service discovery framework for the dynamic mobile environment in terms of accuracy and effectiveness using appropriate metrics and case studies?

1.5 Research Aim and Objectives

The aim of this research is to design a self-adaptive mobile web service discovery framework for a dynamic mobile environment with improved accuracy and effectiveness. To achieve the aim of this research, four (4) objectives are consequential as listed below:

i. To propose a MWS categorization approach for self-adaptive mobile web service discovery in a dynamic mobile environment.
ii. To propose a context model for self-adaptive mobile web services discovery in a dynamic mobile environment.
iii. To propose a self-adaptive matchmaker for MWS discovery in a dynamic mobile environment.
iv. To integrate and evaluate the framework in terms of accuracy and effectiveness using appropriate metrics and case studies.

1.6 Research Scope

In an effort to accomplish the research objectives, the scope of this research is narrowed to the following:

1. This research is related to the discovery of MWS for a dynamic mobile environment. Therefore, other stages of Web Service life-cycles such as the advertisement, selection, composition, and finally, invocation are not dealt with in this study.
2. Protégé has been used to shape the ontology-based context model. While meta-heuristic algorithm is adapted in creating an approach to be used for the MWS categorization and the accuracy of the approach has been evaluated using accuracy percentage as widely used in related research.
3. For the purpose of MWS discovery, the context model is created based on case studies from two domains (Smart Healthcare and Smart Agriculture) for self-adaptive MWS discovery in DME. Therefore, the context model is designed for these domains without barring its applicability in other domains.
4. The results obtained have been validated based on the MWS discovery context. The proposed self-adaptive service discovery framework for the dynamic mobile environment has been compared with existing frameworks using a metrics-based measurement of accuracy and effectiveness for statistical significance as widely used in related research.

1.7 Significance and Expected contributions

The significance of this study can be addressed twofold. Its significance to the Software Engineering Body Of Knowledge (SWEBOK) and its significance to the Software Engineering Practice (SWEP). The results of this research can help software developers to improve the quality of MWS service discovery and service-based software development such as location-based applications, mobile learning, healthcare monitoring, smart farming, and travel agency applications to attain the numerous benefits of web services, thereby saving a large amount of money and time in delivering most relevant MWS despite the high influx of MWS with similar functions

today. So, this research's main beneficiaries include Service-Oriented Computing (SOC) experts, mobile application developers, and mobile users.
Consequently, the expected contributions of this research are as follows;

i. An enhanced fine-grained MWS categorization approach to pave the way for relevant MWS discovery in a dynamic mobile environment.
ii. An enhanced meta context ontology model that representation the heterogeneous context information acquired from various sources to facilitate self-adaptive service discovery in a dynamic mobile environment.
iii. An improved self-adaptive MWS matchmaker and an effective self-adaptive service discovery framework for a dynamic mobile environment.

1.8 Structure of the Thesis

The thesis is organized into the following chapters:

Chapter 2 (the literature review) outlined, reviewed, and discussed the problems by introducing the general information on web service discovery, the current research in the domain of MWS discovery, the sub-domains of MWS discovery, and presents the systematic literature review that followed a well-structured methodology. Chapter 2 also discussed the current trends in the literature, the research gaps found from the current studies, and metrics used to assess the accuracy and effectiveness of MWS discovery frameworks.

Chapter 3 (the research methodology) discussed the methodology that will guide this research appropriately, the scope of this chapter includes the research design, the research framework, the research procedure, the mapping of research phases, research objectives, research question, methodology, and expected deliverables using the goal, question metric method. The experimental settings, the accuracy, and the effectiveness measures used in evaluating the framework are also discussed in this chapter.

Chapter 4 proposes the MWS categorization approach as a phase that precedes the self-adaptive MWS discovery and is based on MWS goals and tags followed by hybridizing k-means and M-NSA.

Chapter 5 proposes a meta context ontology for self-adaptive MWS discovery in DME. The second part of this chapter presents ontology development and evaluation.

Chapter 6 proposes a framework and self-adaptive MWS matchmaker based on a modified negative selection algorithm (M-NSA), which consist of service relevance learning and the self-adaptive MWS matchmaking algorithms to cater for changes in DME, identify the most MWS based on the user request in addition to context and return the most relevant MWS.

Chapter 7 presents the evaluation results self-adaptive MWS discovery framework for DME, which includes the evaluation in the e-learning domain, the service relevance learning experimental evaluation, the MWS discovery experimental evaluation, and the evaluation of the accuracy and effectiveness of the framework.

Chapter 8 presents the thesis's conclusion and highlights the concluding remarks on research objectives, contributions of this study, and recommendations for future works.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviewed the current research in web service discovery and other related studies to get a wider perspective. A Systematic Literature Review (SLR) is conducted in pursuance of unbiased, critical analysis of the current literature in the context of web service discovery in a dynamic mobile environment. This SLR's objectives are twofold (i) develop a more rigorous understanding and identify recent research trends in mobile web service discovery techniques in a dynamic mobile environment; (ii) find noteworthy research prospects and open issues that may guide future research directions appropriately. Finally, web service discovery literature in a dynamic mobile environment is provided together with a critical discussion on the contributions and drawbacks of the discovery approaches in this domain. The rest of this chapter is organized as follows: The Web Service and MWS are discussed in Sections 2.2 and 2.3, respectively. The Mobile Web Service discovery framework is discussed in Section 2.4. The self-adaptive MWS discovery is discussed in section 2.5. The dynamic mobile environment is discussed in section 2.6. The Result of the SLR of MWS Discovery in DME is discussed in Section 2.7. The MWS discovery framework drawbacks and research directions are discussed in Sections 2.8. Finally, in Section 2.9, a summary of the whole chapter is presented. Figure 2.1 provides an overview of the general structure of this chapter.

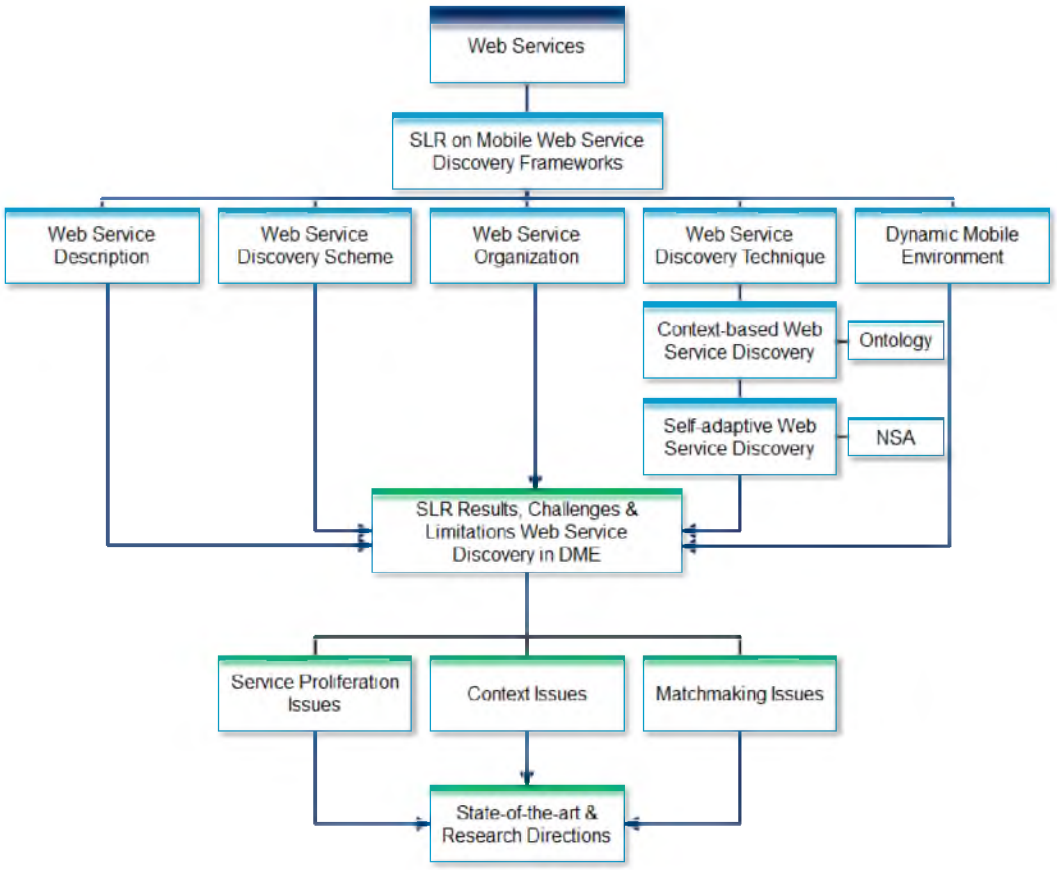

Figure 2.1 Structure of the literature review

2.2 The Web Services

Service Oriented Architecture (SOA) 's fundamental notion is to confront interoperability and heterogeneity challenges through Web Service. Generally, Web Service is defined as a reusable, self-descriptiveness, self-containment, language, and platform independence software paradigm that is defined, published and accessed across the Internet using standard protocols to facilitate the development of distributed systems from existing applications with simplicity and low cost (Fielding, 2000; Berners-Lee et al., 2001; Alonso et al., 2004). Web services can be as simple as Microsoft.Net passport or Google MAP API (Abidi *et al.*, 2014).

Many enterprises are creating mobile applications for different purposes. These applications are typically built to access remotes services that provide the data,

business rules, business processes, and functionalities that the users require. The two web service design and access protocols are Simple Object Access Protocol (SOAP) and Representational State Transfer (REST) (Garriga et al., 2016). SOAP (heavyweight) was developed to replace technologies that depend on binary messaging rather than XML, such as Distributed Component Object Model (DCOM) and Common Object Request Broker Architecture (CORBA), due to their lack of optimal compatibility with the Internet (Mohamed and Wijesekera, 2012). On the other hand, REST (lightweight) depends on a simple URL rather than XML to provide a lightweight alternative where a task can be performed using GET, POST, PUT, and DELETE (AlShahwan et al., 2011). Even though additional information may be requested occasionally as the situation warrants. Unlike SOAP, the availability of REST-based web services that output the data in Command Separated Value (CSV), JavaScript Object Notation (JSON), and Really Simple Syndication (RSS) make it easier to parse within the selected language. The comparison between SOAP and REST is shown in Table 2.1.

Table 2.1 Comparison between SOAP and RESTful web service

Parameter	SOAP	REST
Data Format	XML	XML, JSON, YML, Plain Text, etc. (smaller message formats)
Service is exposed through	Interfaces	URIs
Invocation method	RPC	HTTP Request
System State	Prioritize stateful communication	Prioritize stateless communication
Standards	Follow WS* standards	No official standards
Uses preference	Financial Operation	Social and Mobile Operations
Performance	Slower due to protocol overhead	Faster due to free architectural style
Support for middleware	Yes (due to HTTP, SMTP, FTP)	No (HTTP is sufficient enough)
Operations on data	Support other operations	Support CRUD only

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