

A semantic content based methodology framework for e-government development

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To the Lord Jesus Christ

Abstract

The integration and interoperability of autonomous and heterogeneous electronic government (e-government) systems of government departments and agencies for a seamless services delivery to citizens through one-stop e-government portals remain challenging issues in e-government development. In recent years, Semantic Web technologies have emerged as promising solutions to these problems. Semantic Web technologies base on ontology allow the description and specification of electronic services (e-services), making it easy to compose, match, map and merge e-services and facilitate their semantic integration and interoperability. However, a unified and comprehensive methodology that provides structured guidelines for the semantic-driven planning and implementation of e-government systems does not exist yet. This study presents a methodology framework for the semantic-driven development of future e-government systems. The features of maturity models, software engineering and Semantic Web domains are investigated and employed to draw and specify the methodology framework. Thereafter, the semantic content of the methodology framework is further specified using ontology building methodology and Semantic Web ontology languages and platforms. The study would be useful to e-government developers, particularly those of developing countries where there is little or no practice of semantic content development in e-government processes as well as where little progress has been made towards the development of one-stop e-government portals for seamless services delivery to citizens. Part of the study would also be of interest to novice Semantic Web developers who might use it as a starting point for further investigations.

Keywords: e-Government, Ontology, Ontology Building Methodologies, Methodology Framework, Development Projects, Maturity Models, Software Engineering, Semantic Technologies, Protégé, OWL, RDF, Java Jena API.

Abstrak

Die integrasie en interbedryfbaarheid van autonome en heterogene elektroniese regeringstelsels (e-regeringstelsels) van regeringsdepartemente en -agentskappe vir flinke dienslewering aan landsburgers deur een-stop e-regeringsportale is steeds uitdagende kwessies in e-regering ontwikkeling. Semantiese Web tegnologieë het verrys as belowende oplossings vir hierdie probleme. Semantiese Web tegnologieë, gebaseer op ontologie, neem die beskrywing en spesifisering van elektroniese dienste (e-dienste) in aanmerking, vergemaklik die opstelling, passing, afbeelding en samesmelting van e-dienste, en fasiliteer hul semantiese integrasie en interbedryfbaarheid. Daar bestaan egter nog nie 'n eenvormige en omvattende metodologie wat gestruktureerde riglyne vir semanties-gedrewe beplanning en implementering van e-regeringstelsels verskaf nie. Die kenmerke van bekwaamheids-modelle, sagteware ingenieurswese en Semantiese Web domeine word ondersoek en gebruik om die metodologie-raamwerk te skets en te spesifiseer. Daarna word die semantiese inhoud van die metodologie-raamwerk verder gespesifiseer deur gebruik te maak van ontologie bouende metodologieë en Semantiese Web ontologie tale en platforme. Hierdie studie sal van nut wees vir e-regering ontwikkelaars, spesifiek ontwikkelaars wat hul bevind in ontwikkelende lande waar min of geen semantiese inhoud ontwikkeling toegepas word in e-regeringsprosesse nie en waar min vordering gemaak is met betrekking tot die ontwikkeling van een-stop e-regeringsportale vir flinke dienslewering aan landsburgers. Gedeeltes van die studie sal ook van belang wees vir beginner Semantiese Web ontwikkelaars wat dit kan gebruik as 'n beginpunt vir verdere ondersoeke.

Sleutel woorde: e-Regering, Ontologie, Ontologie Bouende Metodologieë, Metodologie-raamwerk, Ontwikkeling Projekte, bekwaamheids-modelle, sagtewareingenieurswese, Semantiese Tegnologieë, Protégé, OWL, RDF, Java Jena, API.

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List of Abbreviations

AM	Alignment Matrix
API	Application Programming Interface
ASP	Active Server Pages
BKMS	Business Keeper Monitoring System
CNP	Contributions Network Project
DAML	DARPA Agent Markup Language
DOLCE	Descriptive Ontology for Linguistic and Cognitive Engineering
DM	Dubai Municipality
DP	Development Project
DPs	Development Projects
ESOM	e-Government Specific Ontology Models
GTZ	German Agency for Technical Cooperation
IAE	Integrated Acquisition Environment
ICT	Information and Communication Technology
ITAX	Integrated Tax Management System
MM	Maturity Model
MMSL	Maturity Model Stage Layer
NGO	Non-Governmental Organization
OntoDPM	Domain Ontology of Development Projects Monitoring
OL	Ontology Layer
OWL	Web Ontology Language
OWL-S	OWL for Services
POM	Prescribed Ontology Models
RDF	Resource Description Framework
RDFS	RDF Schema
SDK	Software Development Kit
SDL	Software Development Layer
SDM	Software Development Methodology
SE	Software Engineering

SSA	Sub-Saharan Africa
SW	Semantic Web
SWRL	Semantic Web Rule Language
UCD	Use Case Diagram
UK	United Kingdom
UML	Unified Modeling Language
URI	Uniform Resource Identifier
US	United States
WM	Weighing Matrix
WSML	Web Service Modeling Language
WSMO	Web Service Modeling Ontology
XML	Extensible Markup Language
XMLS	XML Schema
ZIMS	Zambia Immigration Management System

Authors' Contributions

The authors' contributions in each of the papers presented in this thesis are as follows:

First author: Literature review; collection of data, design, model and develop ontology; design, plan and write all manuscripts.

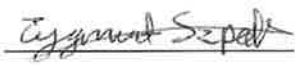
Second author: Critical feedback and discussion on ideas and concepts; general guidance of the first author's research effort; edition of manuscripts.

Third author: Critical feedback on manuscripts; edition of manuscripts.

The following is a statement from the co-authors confirming their individual role in each of the papers presented in this study and giving their permission that the six manuscripts may form part of this thesis.

I declare that I have approved the manuscripts included in this thesis, that my role in the study, as indicated above, is representative of my actual contribution and that I hereby give my consent that they may be published as part of the Ph.D thesis of Jean Vincent Fonou-Dombeu.

Prof. M. Huisman


Mr. Z.L. Szpak

CHAPTER I

Introduction

1.1. Motivation of the Study

Electronic government (e-government) has grown and matured as a field of research in the past ten years with research initiatives being undertaken in various domains including public administration, management science, public and politic, library and information science, marketing and communication, accounting, business and economics, computer science and information systems, etc. (Rodriguez-Bolivar et al., 2010). The aim of the research is to simultaneously address political, institutional, technological, social, and cultural issues for effective online services delivery to citizens.

The multidisciplinary nature of e-government research shows that the development of e-government is a much wider field than software or technologies development. However, the design, implementation and deployment of electronic services (e-services) on the Web for effective online interaction of government with citizens through a single government Web portal or one-stop portal remains a key and challenging priority in e-government development. In fact, e-government has been largely implemented in the form of autonomous and heterogeneous web-based systems in various countries around the world, raising the issue of integrating and interoperating these heterogeneous systems of government departments and agencies towards one-stop e-government portals, where citizens can seamlessly access a large range of government services (tax return, social grants, etc.).

The traditional software engineering methodologies employ Web services standards to address e-services integration and interoperability problems in e-government (Arif, 2008; Lee et al., 2009). However, it has been demonstrated that Web services standards provide only the syntactical representation and description of e-services; they lack the semantic features which are more efficient and reliable (Muthaiyah and Kerschberg, 2008). Therefore, Semantic Web technologies based on ontology have attracted e-government developers in the past seven years as alternative solutions to Web Services standards. A plethora of semantic e-government domain specific ontology models have been developed to describe and specify various aspects of e-government service delivery. With ontology and Semantic Web ontology languages and platforms, it is possible to describe and specify e-services in such a way that

they can be easily composed, mapped, matched and merged to facilitate their semantic integration and interoperability.

However, a unified and comprehensive methodology that provides structured guidelines for the semantic-driven planning and implementation of e-government systems does not exist yet. There are still no clear answers to the following methodological ontology related questions: When and in which circumstance is an ontology needed in e-government development? What kinds of ontologies are appropriate for semantic content representation in e-government processes? What kind of ontology is adequate at a particular phase of e-government development? How does one represent a selected ontology in a given circumstance in e-government development? What is the more efficient way that one can schedule ontology activities in e-government processes such that the aforementioned engineering issues are tackled consistently at various phases of e-government projects? What are the current appropriate tools and platforms for ontology development in e-government?

This study presents a methodology framework for the semantic-driven development of future e-government systems. The features of maturity models, software engineering and Semantic Web domains are investigated and employed to draw and specify the methodology framework. Thereafter, the semantic content of the methodology framework is further specified using ontology building methodology and Semantic Web ontology languages and platforms.

The study would be useful to e-government developers, particularly those of developing countries where there is little or no practice of semantic content development in e-government processes as well as little progress towards the development of one-stop e-government portals for seamless services delivery to citizens. Part of this study would also be of interest to novice Semantic Web developers who might use it as a starting point for further investigations.

1.2. Objectives of the Study

The primary objective of this study is to develop a methodology framework for the semantic-driven implementation of future e-government systems. Secondary objectives are:

- To critically analyse existing ontology engineering techniques,
- To identify appropriate kinds of ontologies for e-government services description and specification,
- To develop a framework for agile application development in e-government,

- To develop a framework for ontology development in e-government,
- To identify software platforms for ontology development in e-government, and
- To conduct a detailed case study of semantic ontology development in e-government processes.

1.3. Methodology

1.3.1. Research Paradigm

This study uses a descriptive paradigm as presented in (Shaw, 2002; Lazaro and Marcos, 2005). The paradigm is a mixture of positivism and interpretive paradigms in the sense that, the study designs and specifies a semantic-driven methodology framework on the one hand and on the other hand, the designed methodology is validated using a qualitative approach.

1.3.2. Research Method

The research method of this study consists of:

1. Studying existing e-government systems development methods and techniques and performing a critical analysis to identify their advantages and disadvantages, and their elements of complementarities.
2. Designing and specifying a new methodology which (i) exploits the advantages of each existing approach, and (ii) uses semantic ontology models in a stepwise based framework to model and specify e-government systems at various phases of e-government development.

The design and specification of the proposed methodology framework rely on the ontology engineering and agile software development techniques.

1.3.3. Research Validation

Following the work of Shaw (2002), a case study of a government service domain is used in this study to validate the proposed semantic-driven methodology framework. The data of the case study is collected using a qualitative approach with interview and literature review. The validation consists of gathering the business requirements of the government service domain and applying the ontology building methodologies to develop semantic

ontology models, from the conceptual to the formal stage, using Semantic Web ontology languages and platforms at various phases of e-government systems development.

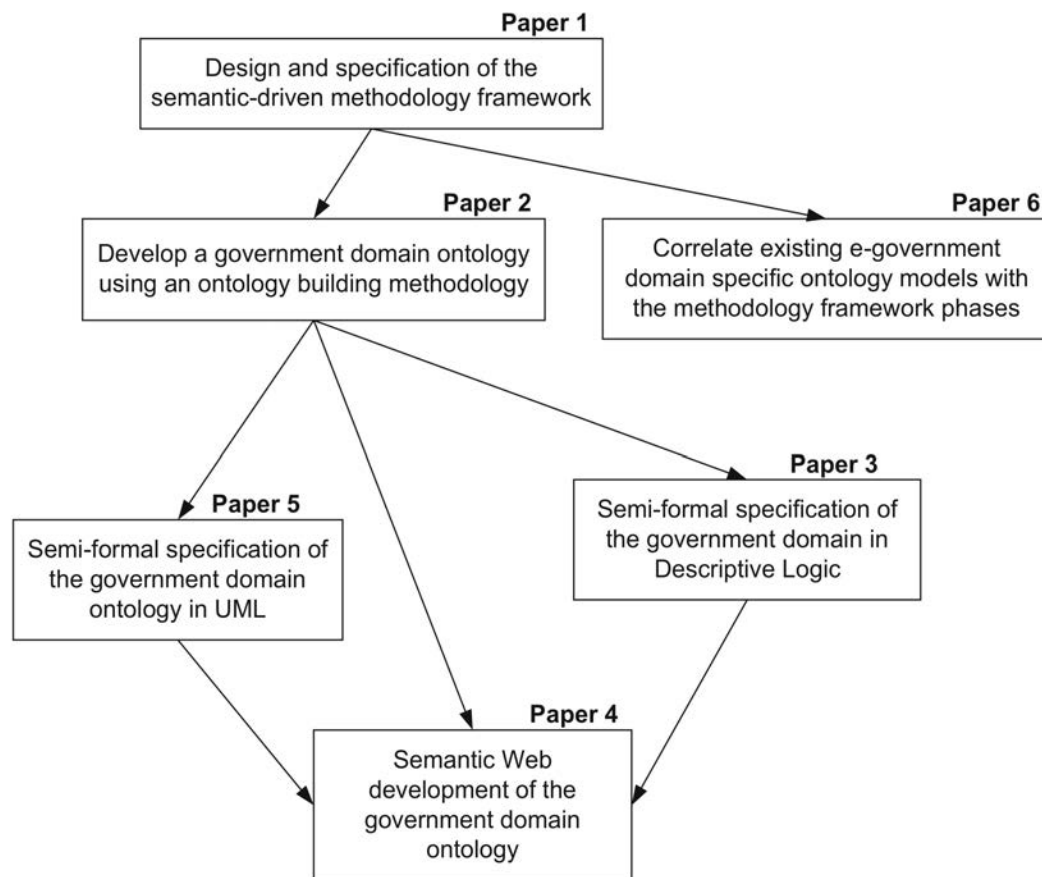


Figure 1: Graphical illustration of the connections between the papers which constitute this thesis.

1.4. Chapters Summary

The research is presented in six papers, contained in Chapter 2 to 7. In the first paper presented in Chapter 2, the methodology framework is drawn and described. A case study of government domain ontology development using an ontology building methodology is described in the second paper presented in Chapter 3. The semi-formal and formal descriptions of the government domain ontology developed in Chapter 3, are carried out in the third, fourth and fifth papers presented in Chapter 4, Chapter 5 and Chapter 6 respectively, using Semantic Web ontology languages and platforms. Chapter 7 presents the sixth paper; this paper established a correlation between existing e-government domain specific ontology models with the phases of the methodology framework presented in Chapter 2. To provide a complete picture of the methodology framework, the second, third, fourth and fifth papers are also cited in the first paper as they are the illustrations of the semantic modelling and specifications in the methodology framework phases. The connection

between the different papers as explained above is illustrated in Figure 1. Furthermore, Table 1 establishes the links between the objectives of the study (See Section 1.2) and the papers that were used to address them.

Table 1: Objectives of the study and papers used to address them

Objectives (1-6)	Paper(s) Addressing the Objectives
1, 2 and 3	Paper 1 and 6
4	Paper 5
5	Paper 4
6	Paper 2 and 3

CHAPTER II

Fonou-Dombeu, J.V. and Huisman, M. "**A Methodology Framework for Semantic-Driven Development of e-Government Systems**", Submitted for review to Government Information Quarterly.

In this paper, we draw and describe the methodology framework based on the features of maturity models, software engineering and Semantic Web domains. Support tools are designed and specified as well. They include a business process model, an alignment matrix and a weighting matrix of maturity models' stages with the framework phases.

The business process model of the methodology framework specifies the mechanism for the iterative and incremental engineering and development of e-government systems; it shows how maturity models stages' requirements, software engineering and Semantic Web techniques could be used simultaneously at each phase of the framework to develop a one-stop e-government portal. The algorithm of the business process model relies on the agile software development paradigm; the business requirements of the e-government service under development is to be revisited and a prototype has to be developed and tested at each iteration; this promotes efficiency and fast development of e-government systems.

The maturity models layer of the methodology framework was specified using the United Nations maturity model's stages. Then, the alignment matrix is used to specify a generalization scheme of maturity models stages alignment to the framework phases. In other words, the alignment matrix specifies how each maturity model stages could be conveniently aligned to the framework phases independently of its number of stages.

The weighting matrix is build to quantify the intensity of Semantic Web activities at various phases of the framework; it appears that semantic activities are more intense at advanced stages of e-services development i.e. at the last phase of the framework.

Parts of this work have been presented in (Fonou-Dombeu and Huisman, 2010a, 2011d).

CHAPTER III

Fonou-Dombeu, J.V. and Huisman, M. (2010) "**Investigating e-Government Knowledge Base Ontology Supporting Development Projects Monitoring in Sub Saharan Africa**", International Journal of Computing and ICT Research, Special Issue Vol. 4, No. 1, pp. 20-29.

In this paper, a case study of government domain ontology is developed. The business requirements of a government service domain are firstly collected. Thereafter, a framework adopted from the Uschold and King (1995) ontology building methodology is employed to build the domain ontology. Finally, the domain ontology is implemented with the ontology knowledge base editor Protégé.

The framework employed provides various steps and tasks that must be performed to define the purposes, delimit the scope, gather the domain concepts and the relationships between them, and build the domain ontology. The Uschold and King (1995) method was chosen here because of its clarity and the fact that it is technology independent; which might facilitate its use by novice ontology developers and promote a quicker development of domain ontology.

CHAPTER IV

Fonou-Dombeu, J.V. and Huisman, M. (2011) "**Semantic-Driven e-Government: Application of Uschold and King Ontology Building Methodology for Semantic Ontology Models Development**", International Journal of Web & Semantic Technology, Vol.2, No. 4, pp. 1-20.

In this paper, the framework employed to build the domain ontology in the second paper presented in Chapter 3 is improved and emphases are placed on the detailed application of the Uschold and King (1995) ontology building methodology.

Additionally, (i) a set of competency questions are used to improve the corpus of concepts of the domain ontology, (ii) a semantic consistency validation of the domain ontology is performed, (iii) an alignment of the domain ontology with the Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE) upper level ontology is done to allow its wider visibility in the ontology engineering community and facilitate its integration with existing *meta* data standards, and (iv) the semi-formal and formal representations of the domain ontology is carried out using the Description Logic and Web Ontology Language (OWL) syntaxes respectively.

The OWL version of the domain ontology is developed based on its Description Logic representation, using Protégé and programming editors such as JCreator, JGrasp and Microsoft Visual Studio.

CHAPTER V

Fonou-Dombeu, J.V. and Huisman, M. (2011) "**Combining Ontology Building Methodologies and Semantic Web Platforms for e-Government Domain Ontology Development**", International Journal of Web & Semantic Technology, Vol.2. No. 2, pp. 12-25.

In this paper, existing Semantic Web ontology languages and platforms are reviewed and a detailed process of semantic development of e-government domain ontology is described. The ontology development process is described from the conceptual till the formal stage and emphases are placed on the definition and application of Semantic Web technologies concepts.

The conceptual stage of e-government domain ontology development is illustrated with the application of the Uschold and King (1995) ontology building methodology presented in the second paper in Chapter 3. Thereafter, the Unified Modelling Language (UML) syntax for knowledge representation is employed to carry out the semi-formal description of the resulting e-government domain ontology. The UML formalism was chosen because of its ease of use and its popularity in the software development community.

State-of-the-art Semantic Web ontology languages and platforms including Resource Description Framework (RDF), OWL, Protégé and Java Jena Application Programming Interface (API) are employed to formally describe and specify the e-government domain ontology. A Java package namely Jena API, configured in the Eclipse software development

kit (SDK) is employed to implement the e-government domain ontology and generate its RDF formal representation. Similarly, Protégé is used to implement and generate the OWL version of the e-government domain ontology.

Finally, the platforms for the persistent storage and query of formal ontology written in Semantic Web ontology languages are discussed.

CHAPTER VI

Fonou-Dombeu, J.V., Huisman, M. and Szpak, Z. (2011) **A Framework for Semantic Model Ontologies Generation for e-Government Applications**, In Proceedings of the 5th International Conference on Digital Society, Gosier, Guadeloupe, France, 23-28 February, pp. 152-158.

This paper presents a framework for the systematic generation of semantic ontology models in e-government projects. The framework starts with an e-government service domain as an input. Domain experts and different information sources are consulted to describe the business process of the domain. A domain ontology is then built to capture the relevant concepts, activities, tasks, regulations and relationships between all the constituents of the e-government service domain. Thereafter, a semi-formal representation of the domain ontology is constructed in the form of a class diagram in UML syntax; this is done by identifying entities and instances in the domain ontology and categorizing relationships between entities (association, composition, inheritance). The semi-formal version of the ontology is created with Protégé and saved onto the disc. Finally, appropriate software is used to import the OWL formal version of the ontology from the file.

CHAPTER VII

Fonou-Dombeu, J.V. and Huisman, M. (2011) **Semantic-Driven e-Government: Correlating Development Phases with Semantic e-Government Specific Ontology Models**, In Proceedings of the 11th European Conference on e-Government, Ljubljana, Slovenia, 16-17 June, pp. 245-253.

In this paper a correlation scheme of existing e-government specific ontology models being developed in various researches and projects with the phases of e-government development is presented. Firstly, a literature review is carried out in both e-government and

ontology engineering domains to identify existing ontology models. As a result, e-government specific ontologies (e-government domain) and prescribed ontologies (ontology engineering domain) are identified. Thereafter, a semantic alignment of both categories of ontologies is established. The alignment result and the methodology framework presented in Chapter 2 are used to correlate the e-government specific ontologies with the phases of e-government development.

CHAPTER II

Paper 1:

A Methodology Framework for Semantic-Driven Development of e- Government Systems

A Methodology Framework for Semantic-Driven Development of e-Government Systems

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Abstract

In recent years Semantic Web technologies have emerged in the field of electronic government (e-government) as promising tools for the description and specification of electronic services (e-services) which permit their semantic integration and interoperability and promote the development of one-stop e-government portals for seamless services delivery to citizens. However, a comprehensive methodology which provides structured guidelines for the planning and semantic-driven development of e-government systems does not exist yet. This study presents a methodology framework which amalgamates features from maturity models, software engineering and Semantic Web research domains for a unified and agile semantic-driven development of e-government systems. Firstly, the methods and techniques currently used for the planning, design, and implementation of e-government systems worldwide are investigated; a critical analysis is carried out to identify their advantages and disadvantages, as well as their contribution towards addressing the aforementioned engineering issues. Secondly, the proposed methodology framework is drawn and specified. Finally, support tools including a business process model, an alignment matrix of stages and phases of development and a weighting matrix of the intensity of semantic activities at various phases of development are drawn and described. The aims of the study are twofold: (1) providing direction for the semantic-driven development of future e-government systems which would facilitate their integration and interoperability towards one-stop e-government portals, and (2) unifying the currently used methods and techniques for efficient planning and implementation of future e-government systems based on semantic technologies. The main contribution of the study is the investigation and amalgamation of features from the maturity models, software engineering and Semantic Web research domains to enable the planning and agile semantic-driven implementation of future e-government systems. The research would be of interest to e-government project teams, particularly those of developing countries where little or no progress has been made towards the development of one-stop portals for seamless services delivery to citizens.

Keywords: e-Government; Methodology Framework; One-Stop Portal; Ontology; Semantic Technologies; Maturity Models

1. Introduction

In recent years, many countries worldwide have adopted e-governance, resulting in the development of several web-based applications in various government departments and agencies for online services delivery to citizens. The increasing number of these autonomous e-government applications has given rise to several software engineering issues such as reusability, maintenance, integration and interoperability of these applications (Choudrie and Weerrakody 2007; Muthaiyah and Kerschberg 2008; Lee et al. 2009; Saekow and Boonmee 2009), in the context of one-stop e-government which requires e-government applications to be accessed at a single point and function as a whole for better efficiency and seamless services delivery to citizens (Wimmer 2002; Lee et al. 2009).

On the other hand e-government is a broad research field with several research initiatives being undertaken in various domains (Lofstedt 2005) aiming at simultaneously addressing political, institutional, legal, technological, cultural and social issues for effective electronic services (e-services) delivery to citizens. However, the development and deployment of e-services in a one-stop portal/shop

remains a key and challenging priority in e-government development. In fact, e-government strategies of various countries include e-services development as vehicles for effective online services delivery to citizens and stakeholders. Examples from countries with successful e-government implementation include Singapore (Devadoss et al. 2003), Australia (Teicher and Dow 2002), Taiwan (Sang et al. 2005) and the United Kingdom (Beynon-Davies 2005). Studies reporting on the implementation of successful e-government show that few countries have reached the stage of a one-stop portal where citizens can seamlessly access all government's services; in fact, a United Nations survey in 2002 reported that amongst its 190 member states, only 26 out of 169 websites had one-stop portals and less than 20 offered online transactions (Chen et al. 2006). Therefore, it is important to look at appropriate methodologies for developing e-government applications that provide structured guidelines for the design, implementation and deployment of various government services on the Web to citizens, while consistently addressing the aforementioned engineering issues in an incremental and iterative manner, towards one-stop e-government portals. A review of the current

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literature in e-government implementation has allowed the identification of three main methods and techniques that deal with the planning, design, implementation and deployment of e-services for effective online services delivery to citizens; these include maturity models (MM), software engineering (SE) and Semantic Web (SW) techniques.

Considerable research has been conducted by public administrators for e-government planning and implementation. These studies propose different stages for the development of e-government in maturity models or stage of growth models (Layne and Lee 2001; Howard 2001; Deloitte and Touche 2001; Moon 2002; United Nations 2003; West 2004; Zarei et al. 2008; Bri 2009). A maturity model or stage of growth model is designed as a sequence of stages of e-government growth and constitutes a guiding and benchmarking tool for e-government planning and development. Each stage of the maturity model prescribes a list of web features that are needed online or mechanisms required to create changes at that particular stage of e-government development. An example of e-government initiative that has used the Layne and Lee (2001) model is the Integrated Acquisition Environment (IAE) e-government project in the US (Sang et al. 2005). The shortcoming of maturity models or stage of growth models is that they lack design guidelines throughout their various stages. Furthermore, maturity models emphasize e-government services integration at advanced stages of e-government growth but they do not mention how this can be done. A detailed review of maturity models is carried out later in this study. Despite their shortcomings mentioned above, maturity models provide useful methodological features for e-government planning and development (Estevez et al. 2007). However, the aforementioned shortcomings could be addressed with software engineering and Semantic Web techniques as described below.

In the software engineering field, it is believed that an e-government application is a software system; existing software development methodologies (SDM) are used in e-government projects and existing standards are employed for services integration and interoperability (Vassilakis et al. 2002; Heeks 2006; Janowski et al. 2007; Salhofer and Ferbas 2007; Sanati and Lu 2007; Arif 2008; Lee et al. 2009). In this research, existing SDM or traditional software engineering techniques refers to structured and object-oriented analysis and design methods, and agile methods. The advantages of software engineering techniques is that they provide a large range of tools and mechanisms for analyzing and describing the requirements of the complex public administration systems (Arif 2008; Janowski et al. 2007; Lee et al. 2009), and provides platforms for implementing and deploying web-based e-government applications. However, traditional software development methodologies are inappropriate for the planning and benchmarking of e-services development as it is done with maturity models. Furthermore, the traditional

software engineering techniques use existing Web services standards for e-services integration and interoperability as described in Arif (2008) and Lee et al. (2009). However, Muthaiyah and Kerschberg (2008) have demonstrated that existing Web services standards provide only syntactical interoperability and that the trend is towards semantic interoperability which is more reliable. This is in line with the work of Sanati and Lu (2007) who argued that traditional software engineering methodologies provide only limited solutions to the problem of services integration in e-government. They recommended that more research work be carried out to develop new methodological approaches that provide appropriate solutions to the integration problem in e-government. To this end, semantic technologies have emerged in recent years as promising solutions to the aforementioned engineering problems in e-government (Muthaiyah and Kerschberg 2008; Sabucedo et al. 2010).

The Semantic Web techniques use ontology to describe and specify e-government systems (Apostolou et al. 2005a, 2005b; Xiao et al. 2007; Muthaiyah and Kerschberg 2008; Sanati and Lu 2009; Sabucedo et al. 2010), facilitating their semantic integration and interoperability. The advantage of Semantic Web techniques is that they provide efficient and reliable solutions to the engineering issues of integration, reusability, maintenance and interoperability in e-government (Sanati and Lu 2007; Muthaiyah and Kerschberg 2008). Further, the Semantic Web techniques share some tools and platforms with traditional software engineering techniques (Sanati and Lu 2007) for the analysis and design of e-services, and the development of web-based e-government applications. However, the semantic ontology models being developed in the e-government domain are mainly *ad hoc* solutions and are not aligned to any e-government development phases or stages as proposed by maturity models. This may lead to planning and benchmarking a semantic-driven e-government development project extremely difficult. Furthermore, various ontologies have been used in different research projects for the modeling and specification of e-services, but it is unclear which kinds of ontologies were used (Muthaiyah and Kerschberg 2008; Saekow and Boonmee 2009) and when and in which circumstances of e-services development processes the proposed ontologies are required (Apostolou 2005b; Xiao et al. 2007; Muthaiyah and Kerschberg 2008; Salhofer et al. 2009; Saekow and Boonmee 2009; Sanati and Lu 2009), nor how to represent them from the complex public administration system (Apostolou 2005b; Xiao et al. 2007; Muthaiyah and Kerschberg 2008; Saekow and Boonmee 2009; Sanati and Lu 2009; Sabucedo et al. 2010). Finally, to the best of our knowledge, none of the current semantic based e-government solutions provides a holistic and comprehensive methodology for a semantic-driven planning and implementation of e-government systems.

This study presents a methodology framework which amalgamates features from maturity models, software

engineering and Semantic Web research domains for the planning and agile semantic-driven development of future e-government systems. Firstly, the methods and techniques currently used for the planning, design, and implementation of e-government systems worldwide are investigated; a critical analysis is carried out to identify their advantages and disadvantages, as well as their contribution towards addressing the aforementioned engineering issues. Secondly, the proposed methodology framework is drawn and specified. Finally, support tools including a business process model, an alignment matrix of stages and phases of development and a weighting matrix of the intensity of semantic activities at various phases of development are drawn and described. The aims of the study are twofold: (1) providing direction for the semantic-driven development of future e-government systems which would facilitate their integration and interoperability towards one-stop e-government portals, and (2) unifying the currently used models and techniques for efficient planning and implementation of future e-government systems based on semantic technologies. The main contribution of the study is the investigation and amalgamation of features from the maturity models, software engineering and Semantic Web research domains to enable the planning and agile semantic-driven implementation of future e-government systems. The research would be of interest to e-government project teams, particularly those of developing countries where little or no progress has been made towards the

framework. The methodology of the study is explained in Section 3. Section 4 draws the flowchart of the business process model of the proposed methodology framework. Related studies are presented in Section 5. Section 6 describes a general scheme of maturity models stages alignment with the framework phases, the weighting of ontology activities at various phases of the framework as well as the limitations and future trends of the study. A conclusion ends the paper.

2. Presentation and specification of the proposed methodology framework

The proposed methodology framework architecture is depicted in Fig. 1. It displays an overlay of features from maturity models (top layer), software engineering (middle layer) and Semantic Web (bottom layer) domains, in three phases of e-government systems development namely: scope definition, identification and categorization of services and Web service development. The next subsections specify the layers, phases and semantic content of the methodology framework.

2.1. Specification of the framework base on its layers

First of all, from a software engineering perspective, e-government systems implementation entails gathering the requirements of the government services to be delivered online to citizens, analyze, design, implement and deploy

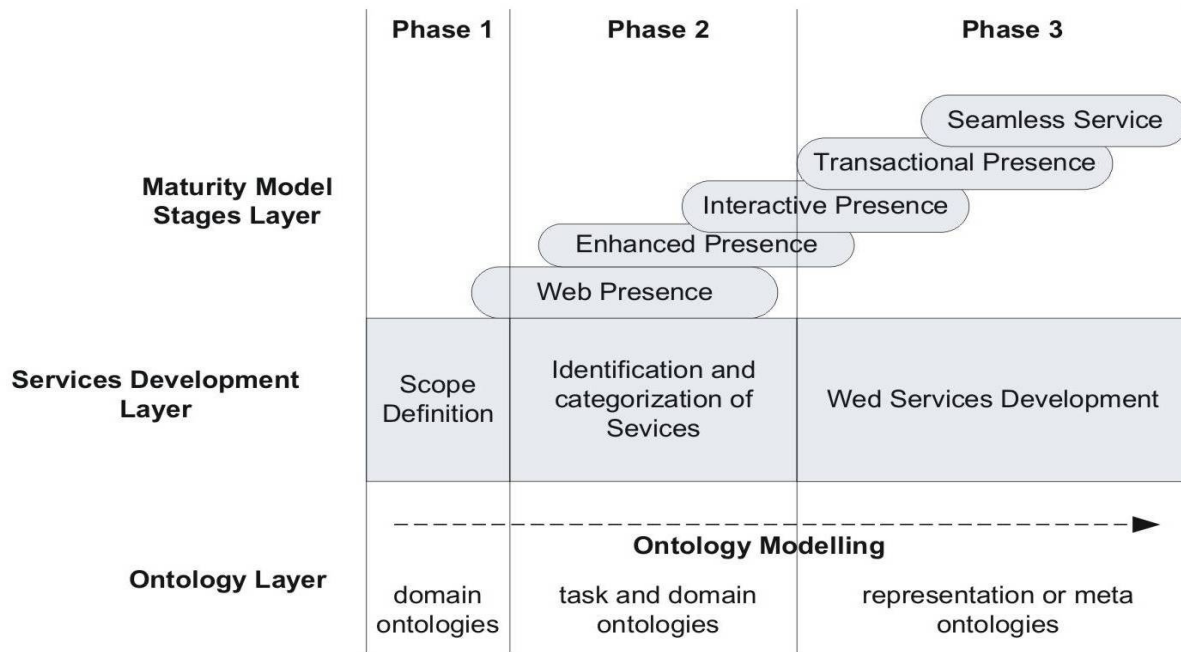


Fig. 1: Proposed three phase methodology framework for semantic-driven development of e-government systems

development of one-stop portals for seamless services delivery to citizens.

The rest of the paper is organized as follows. Section 2 presents and describes the proposed methodology

the e-service on the Web for online interaction with citizens; these processes could be carried out iteratively and incrementally with state-of-the-art software engineering techniques. In view of the complexity of the public

administration system, e-government implementation as described above requires, (1) mechanisms for the planning and implementation of e-services at various stages or phases of e-government development, (2) state-of-the-art software engineering techniques and platforms for the design and implementation of e-services, as well as (3) emerging technologies as the Semantic Web technologies which have potential to facilitate the integration and interoperability of e-services towards one-stop e-government (Muthaiyah and Kerschberg 2008). The framework in Fig. 1 is composed of three layers namely maturity model stages layer (MMSL), services development layer (SDL) and ontology layer (OL). The MMSL provides various stages for e-government development as illustrated with the United Nations maturity model stages in Fig. 1. Each stage prescribes the web features that should be implemented and launched on the government web portal for online interaction with citizens. The stages are complemented with software engineering and Semantic Web tools and techniques at various phases of the framework to enable effective design, implementation and deployment of the prescribed web features of maturity models. At each phase of the framework, the SDL and OL provides system analysis and design techniques as well as platforms for the implementation and deployment of the required web features at the corresponding maturity model stage(s). In particular, the SDL provides state-of-the-art software engineering techniques as object-oriented and agile methods for the design and development of e-services. Furthermore, if the proposed framework phases may not be followed chronologically or in a linear order in practice, then, agile methods at SDL provide mechanisms for the iterative and incremental development of e-services through a continuous review of e-services requirements and prototyping to enable the quick development of required e-services (Greg et al. 2006). The OL provides various ontology models that capture at each phase of the framework the semantic content of e-services under development; the resulting e-services ontology models are implemented in Semantic Web ontology languages such as Extensible Markup Language (XML), Resource Description Framework (RDF) and Web Ontology Language (OWL) with Semantic Web platforms to enable their easy composition, matching, mapping and merging and facilitate their integration and interoperability towards one-stop e-government.

2.2. Specification of the framework base on its phases

As shown in Fig. 1, the SDL of the framework proposes three phases of e-government application development namely: scope definition, identification and categorization of services, and web services development (See SDL in Fig. 1). The scope definition phase is the analysis phase in which the scope of the e-government project has to be circumscribed. This could be done by identifying the key functions of the corresponding government department or agency that will be concerned by a move to electronic

public services, the intellectual and technological resources needed, and the laws or legislations regulating the domain. After the scope of the e-government project has been delimited, the services identification and categorization commences. At this phase, each domain function identified previously should be analysed and designed into potential electronic services; related services across different functions should be grouped into the same category. The grouping of services should be done according to the ultimate goal of achieving the electronic accomplishment of the related functions. The web services development phase deploys the required resources (programming platforms and technologies) to effectively realize the electronic delivery of the intended services. This phase does not end; it continues throughout the remaining stages of the maturity models and continuously improves the level of sophistication of e-services (interactivity, transaction, seamless services) required by the maturity models.

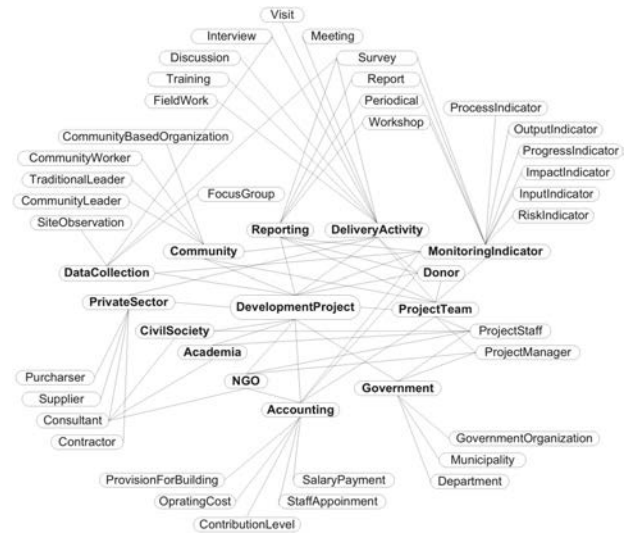


Fig. 2: OntoDPM domain ontology

2.3. Specification of the semantic content of the framework

The study suggests that domain ontology (Gomez-Perez and Benjamins 1999; Beck and Pinto 2003) be constructed in the first phase of the proposed e-government application development framework (See OL in Fig. 1). The domain ontology will capture the relevant vocabularies about the concepts and their relationships, as well as the activities and the laws or regulations that govern the related functions of the corresponding government department or agency (Gomez-Perez and Benjamins 1999). The domain ontology at this stage should be written in an informal language (Uschold 1996; Gangemi et al. 1999). An example of domain ontology for development programmes monitoring (OntoDPM) in a developing country is depicted in Fig. 2 and Fig. 3.

The OntoDPM was built in Fonou-Dombeu and Huisman (2010b) as a proof of concept in the methodology framework. In fact, in Fonou-Dombeu and Huisman

(2010b) a framework adopted from the Uschold and King (1995) ontology building methodology is employed to define the purpose, delimit the scope, gather the concepts and activities of the domain and build the OntoDPM as in Fig. 2; this provide a useful example of how a domain ontology could be built in a particular phase of the proposed methodology framework. The OntoDPM in Fig. 2 shows the key concepts of the domain (people, stakeholder, financier, monitoring indicator, reporting technique, etc.), the activities carried out in the domain (training, discussion, fieldwork, visit, meeting, etc.) and the relationships between the constituents of the domain.

Domain and task ontologies are suggested in the second phase (See OL in Fig. 1); this means that domain ontologies could be constructed to describe particular services and one or many task ontologies to demonstrate how the corresponding services could be achieved in the real world interaction with citizens and stakeholders.



Fig. 3: Protégé version of the OntoDPM domain ontology

At this phase we suggest that domain and task ontologies be realized in the semi-formal language (Uschold 1996). The semi-formal versions of the OntoDPM domain ontology in UML and Description Logic were written in Fonou-Dombeu and Huisman (2011a, 2011d) respectively, as a proof of concept in the methodology framework; these studies describe in detail how one can transform domain ontology into its semi-formal version at a particular phase of the methodology framework.

In the web services development phase (third phase in Fig. 1) of the framework, e-services will need to be automatically composed, mapped, matched and merged to facilitate their semantic integration and interoperability towards one-stop e-government portals. Therefore, the domain and task ontologies created previously should be

rewritten in a more advanced formalism as provision for their integration and interoperability; the representation or meta ontologies are appropriate at this phase (Uschold 1996; Gomez-Perez and Benjamins 1999; Gangemi et al. 1999). Once more, we have created as a proof of concept, the formal versions of the OntoDPM in OWL and RDF in Fonou-Dombeu and Huisman (2011a, 2011b) respectively, using state-of-the-art Semantic Web ontology development platforms including Protégé and Java Jena API. A part of the formal representation of the OntoDPM domain ontology in Fig. 1 in OWL is depicted in Fig. 4. The issue of effective integration of e-services is out of the scope of this study; some techniques for integrating or mapping the resulting formal ontologies at the third phase of the methodology framework are described in (Yannis and Marco 2003; Chen et al. 2007). The methodology of the study is presented in the next section.

```

<owl:Class rdf:about="#Person"/>
<owl:Class rdf:about="#ProjectStaff">
  <rdfs:subClassOf rdf:resource="#Person"/>
</owl:Class>
<owl:Class rdf:about="#CommunityLeader">
  <rdfs:subClassOf rdf:resource="#Person"/>
</owl:Class>
<owl:Class rdf:about="#CommunityWorker">
  <rdfs:subClassOf rdf:resource="#Person"/>
</owl:Class>
<owl:Class rdf:about="#TraditionalLeader">
  <rdfs:subClassOf rdf:resource="#Person"/>
</owl:Class>
<owl:Class rdf:about="#Financier"/>
<owl:Class rdf:about="#Donor">
  <rdfs:subClassOf rdf:resource="#Financier"/>
</owl:Class>
<owl:Class rdf:about="#Government">
  <rdfs:subClassOf rdf:resource="#Financier"/>
</owl:Class>
<owl:Class rdf:about="#NGO">
  <rdfs:subClassOf rdf:resource="#Financier"/>
</owl:Class>
  
```

Fig. 4: Part of OWL code of the OntoDPM

3. Research methodology

Several journals, conference papers, research reports and magazines on e-government published between 2000 and 2010 inclusive were reviewed. The aim was to investigate the current methods and techniques used in e-government systems development worldwide. Firstly, the selection of relevant papers was done by means of a keyword search in the Google search engine. Keywords included "e-government development", "e-government development methodology", "e-government development framework", "e-service development", "semantic e-government", "semantic-driven e-government", " e-government in country"; where country include US, UK,

Singapore, etc, which are countries with successful e-government implementation experiences (Chen et al. 2006).

In total, 244 related research works were downloaded. The content analysis of the downloaded research was carried out based on the title and abstract; in certain cases, the introduction and selected sections were analysed as well. As a result, (1) research which focused on e-government development methodology or framework in general i.e. which addressed general issues such as adoption, strategies, etc., and (2) research which did not focus on or discuss processes for e-government systems development, e-services development, or semantic web integration and interoperability of e-services was discarded. Fifty nine (59) research reports that met the abovementioned criteria remained. The remaining research papers were read and analysed thoroughly; finally, journal articles, conference papers as well as research reports from specialized institutions as the United Nations that were accessible were selected. The selected papers were obtained from peer reviewed journals, conferences and magazines: Electronic Journal of E-government (EJEG), International Journal of Electronic Government Research (IJEGR), Government Information Quarterly, Public Administration Review (PAR), Journal of Theoretical and Applied Electronic Commerce Research (JTAER), Journal of Expert Systems with Applications (JESA), Electronic Markets (EM), The International Information & Library Review, Government Finance Review, International Federation for Information Processing (IFIP), European Conference on E-government (ECEG), International Digital Government Research Conference (IDGRC), IEEE International Conference on Wireless Communication, Networking and Mobile Computing (WiCOM), CMA Management, etc.

A thorough analysis of these selected research, showed that, methods and techniques that are widely used for the planning, design and implementation of e-government systems included, (1) maturity models or stages of growth models which prescribe iterative processes of development through various stages (Layne and Lee 2001; United Nations 2003; West 2004), (2) software engineering techniques including structured, object-oriented, and agile methods (Vassilakis et al. 2002; Heeks 2006; Janowski et al. 2007; Salhofer and Ferbas 2007; Sanati and Lu 2007; Arif 2008; Lee et al. 2009) and (3) Semantic Web technologies (Saekow and Boonmee 2009; Sanati and Lu 2009; Sabucedo et al. 2010). Then, the current e-government systems development methods and techniques that dealt with e-services planning, design, and implementation were classified into three main categories namely: Maturity Models (MM), Software Engineering (SE) and the Semantic Web (SW). These three classes correspond to the three layers of the proposed methodology framework in Fig. 1. Table 1 presents some of the selected research papers that were reviewed in this study. Furthermore, some of the papers reviewed described practical experiences of e-government implementation processes; these papers are presented in Table 2.

It is worth noting that Table 2 does not refer to developed countries with successful e-government implementation experiences such as US, UK, Singapore, etc. since detailed studies on the software development techniques or processes of their e-governments systems were unavailable. In fact, the available research mainly reported or evaluated the implementation strategies of e-government systems of these developed countries as well as their success and/or failure factors without providing any information on the software engineering methods or techniques employed for e-services design and implementation. This situation is in part justified by the fact that in these countries, e-government systems implementation is mainly outsourced by private companies which are known to protect their proprietary information; examples include the implementation of the e-government system of the department of Inland Revenue in the UK (Beynon-Davies 2005), the Government Electronic Business (GeBIZ) procurement system in Singapore (Devadoss et al. 2003) and the e-Tax system of the National Tax Agency in Japan (Chatfield 2009). The business process model of the proposed methodology framework in Fig. 1 is presented in the next section.

Table 1
A selection of the research articles reviewed in this study

Authors	E-government Subject	Methods and Techniques
Lee et al. (2009)	Interoperability	SW
Arif (2008)	Implementation case study	SE
Salhofer et al. (2009)	Services integration	SW
Bri (2009)	Planning and implementation	MM
Saekow and Boonmee (2009)	Interoperability	SW
Choudrie & Weerakody (2007)	Process integration	MM
Layne & Lee (2001)	Planning and implementation	MM
West (2004)	Planning and implementation	MM
Moon (2002)	Planning and implementation	MM
Muthaiyah & Kerschberg (2008)	Interoperability	SW
Sabucedo et al. (2010)	Integration and interoperability	SW
Zarei et al. (2008)	Planning and development	MM
Sanati & Lu (2009)	Service integration	SW
Apostolou et al. (2005a, 2005b)	E-service development, maintenance and integration	SW
Klischewski & Jeenicke (2004)	Implementation case study	SE
Xiao et al. (2007)	Interoperability	SW
Salhofer & Ferbas (2007)	Implementation case study	SE
Janowski et al. (2007)	Development framework	SE
Vassilakis et al. (2002)	Implementation case study	SE
Heeks (2006)	Implementation life cycle	SE

4. Flowchart of the business process model of the methodology framework

As shown in Fig. 1, the service development layer (middle layer) provides the names of the framework phases: scope definition, identification and categorization of services, and web services development. It represents the process of e-services development, from the requirements of a government’s business domain to the effective e-services implementation. Fig. 5 depicts the flowchart of the business process model of the methodology framework in Fig. 1; it describes the incremental and iterative engineering process for realizing the web features prescribed by the maturity models stages, at each phase of the framework. Table 3 describes the variables used in the flowchart.

Table 2
List of research studies describing e-government implementation case studies

Authors	Government Department/ Agency	Country
Arif (2008)	Dubai Municipality	Dubai
Lee et al. (2009)	Hong Kong Government	China
Saekow & Boonmee (2009)	Thailand Government	Thailand
Klischewski & Jeenicke (2004)	City of Hamburg	Germany
Salhofer & Ferbas (2007)	City of Graz	Austria
Vassilakis et al. (2002)	Greek Ministry of Finance	Greece
Bri (2009)	Irish Revenue Offices	Ireland

Table 3
Variables of the business process model algorithm

Variables	Description
<i>np</i>	Number of framework phases (1 to 3)
<i>ns</i>	Maturity model number of stages
<i>max</i>	Maximum number of phases or stages
<i>WF</i>	Web features
<i>MM</i>	Maturity model
<i>OM</i>	Ontology model
<i>x</i>	Pace of increment

The incremental and iterative process in Fig. 5 follows the agile software development paradigm (Greg et al. 2006; Clutterbuck et al. 2009); it commences with the selection of a maturity model. This means that, at the beginning of an e-government project, a maturity model has to be chosen. The chosen maturity model will provide the stages of development as well as guidelines for the planning and implementation of the system from a simple web presence to a one-stop portal. Further, each maturity model will provide the web features required at each stage of e-government growth. After having chosen the appropriate maturity model, its stages need to be aligned to the framework as described later in this study. Thereafter, the iteration starts with the first phase of e-services development (see the outer loop in Fig. 5). At each phase of development an iterative process is performed (see the inner loop in Fig. 5) to realize and launch the web features required by the maturity model stages aligned to the corresponding phase of the methodology framework; at each iteration of the process (see the inner loop in Fig. 5),

the web feature under development should be described, its requirements collected in consultation with end-users who are the citizens and civil servants, and its semantic content captured with the prescribed semantic ontology models. Thereafter, if an integration is needed i.e. a government web portal exists and the e-service being developed is to be integrated with the components of this existing system, the architecture of the integration must be designed, a similarity check of the e-services ontology models (those of the current system and the new e-service) performed and the mechanisms and techniques (composition, mapping, merging, etc.) for the integration chosen.

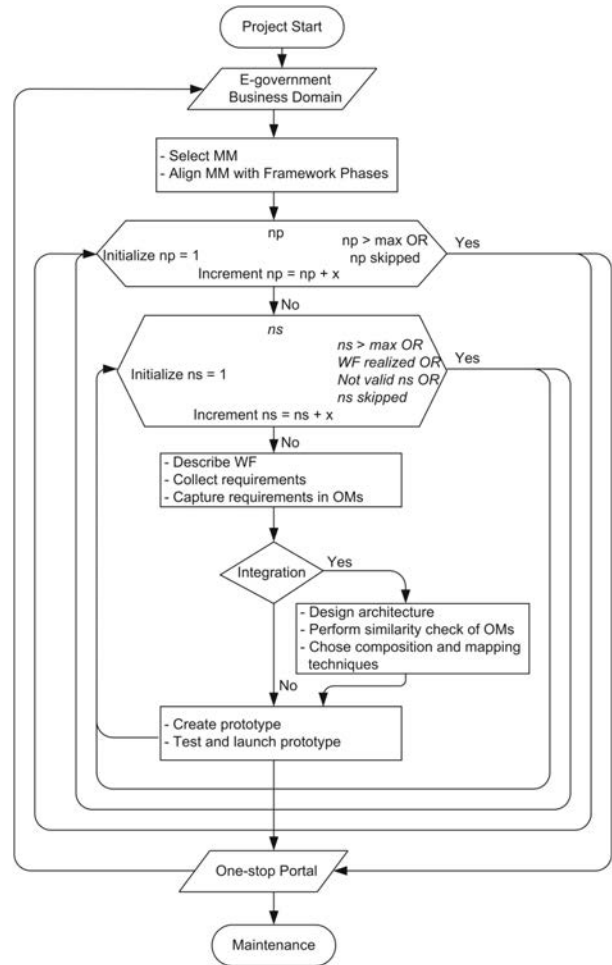


Fig. 5: Flowchart of the business process model of the methodology framework

In all the cases (whether integration is needed or not), a prototype has to be developed, tested and launched onto the government web portal or the resulting prototype from the previous iteration has to be improved and tested. The iterative process is performed until the required web features are realized at that particular phase, or the required web features are to be completed in the next phase of the framework as shown in Fig. 1 with the United Nations maturity model stages. After all the web features or

changes required by the maturity model stages aligned to the current methodology framework phase have been realized, the iterative process continues to the next phase of the framework.

The requirements of the e-government business domain are revisited during iterations (See the inner loop in

5. Related Works

In this section, related work describing the practices of maturity models, software engineering and Semantic Web techniques in e-government are presented.

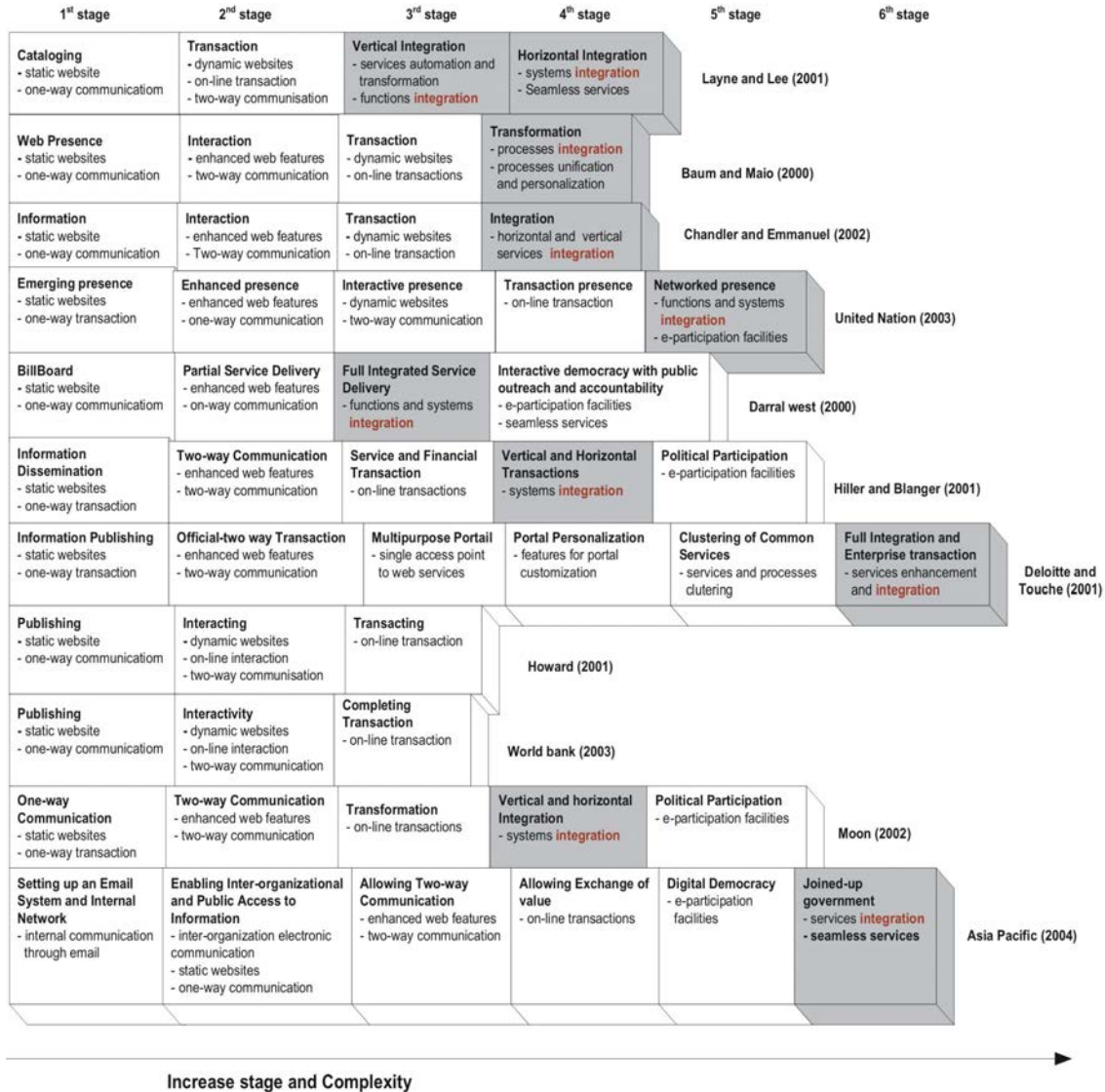


Fig. 6: Summary of eleven existing e-government maturity models with stages of services integration highlighted

Fig. 5) to ensure that the prototype systems developed meet the requirements of users who are the citizens and civil servants. The process is repeated until all the web features or changes prescribed by the maturity model are realized i.e. until a complete one-stop portal is implemented. The phases of the framework might not be followed in a linear order in practice; then, the business process model in Fig. 5 allows a direct selection of a particular phase in order to implement and launch a desired web feature on the government web portal. Related studies are described in the next section.

5.1. Maturity models

A number of maturity models have been developed to guide and benchmark e-government development. A comprehensive review of these maturity models can be found in (Siau and Long 2005; Karokola and Yngstrom 2009). For the purpose of this research, we have studied eleven of these maturity models, which correspond to those described by Karokola and Yngstrom (2009) including: Baum and Maio (2000), West (2000), Layne and Lee (2001), Deloitte and Touche (2001), Howard (2001), Hiller

and Blander (2001), Moon (2002), Chandler and Emanuel (2002), World Bank (2003), United Nation (2003) and Asia Pacific (2004). The maturity models studied in this research are described in Fig.6; they consist of three to six stages each; a summary of their stages is provided in Fig. 6. The stages involving e-services integration have been highlighted to distinguish them from the stages below or above them.

5.2. Software engineering techniques

This section presents some research and projects that have employed traditional software engineering techniques in e-government projects. The Interoperability Framework (IF) of the Hong Kong Government is presented by Lee et al. (2009). The IF provides system analysts and developers with an integrated schema design methodology which covers modeling techniques including business process modeling, data modeling and XML schema definition. The technical specifications of the IF recommend Web Service Standards for the functional integration of applications. Lee et al. (2009) reported that many e-government projects have already applied the IF and that the Macao e-government project was in the process of adopting the IF.

Another e-government development experience from the Dubai Municipality (DM) is presented by Arif (2008). The e-government development team from the IT department of the DM is composed of four major role players, namely: service custodian, business analysts, system analysts and programmers. The service custodian manages the entire process of converting a traditional DM service into an online service and oversees the maintenance of the online service after implementation. The business analysts are in charge of documenting the process flow of a service prior to system design and implementation in collaboration with the relevant department within the municipality. After documenting the process flow of a service, system analysts are responsible for designing the system; they create the data flow diagrams, entity relationship diagrams and UML diagrams. The implementation or coding of the system is carried out by the programmers after the design. Programmers also take care of any required modification post-implementation. Further, one of the functions of the system development section of the IT department of the DM is to prepare and determine the technical criteria and standards for the development of systems, databases and programming languages (Arif 2008).

A well formalized framework for e-government development based on software engineering techniques is proposed by the e-government research team at the Centre of Electronic Government of the United Nations University in China (Janowski et al. 2007). Janowski et al. (2007) view an e-government project as an ensemble of activities: survey, training and development, dissemination, and research tasks. The development activity is carried out using a waterfall software development approach with four steps namely: requirements, modeling, design, and implementation.

Salhofer and Ferbas (2007) present the methodological approach they have used during the development of the city of Graz's e-government platform in Austria. At the beginning of the project, the most important goals, requirements and constraints were defined including intensive usage of open source software and integration of existing and upcoming standards in the e-government field. Thereafter, a spiral software engineering process model, adopted from Barry Boehms (Salhofer and Ferbas 2007) was chosen for the iterative development of the e-government platform.

The experience of the Greek Ministry of Finance's e-services lifecycle is presented in Vassilakis et al. (2002). The authors describe how a software engineering approach was used to develop the electronic tax return system of the Ministry. The lifecycle of the project was comprised of the following steps: requirements analysis, design, implementation and maintenance (Vassilakis et al. 2002).

5.3. Semantic Web techniques

Research and projects that have applied Semantic Web technologies in e-government are presented in the next few lines.

In Sabucedo et al. (2010), an intelligent platform to host e-government services in the form of a customer-oriented e-government Web portal is presented. The authors introduced the concept of intelligent document and Life Event services, both of which are semantically modelled with OWL ontology; this allows services and related public administration interoperability.

Apostolou et al. (2005a, 2005b) present a software engineering platform for the development and management of e-government services namely ONTOGOV. The ONTOGOV platform uses Semantic Web technologies including OWL Simple (OWL-S) and Web Service Modeling Ontology (WSMO) to construct eight kinds of ontologies characterizing the e-government domain. They include legal, organizational, life-cycle, domain, service, life-event, profile and web service orchestration ontologies. These ontologies are aimed at describing and composing services provided by public administrators. In particular, the life-cycle ontology is used to carry out the maintenance of e-services and the web service orchestration ontology is used for software components and service ontology integration (Apostolou 2005b).

A multilevel abstraction of life-events for e-government services integration is presented in Sanati and Lu (2009); a life-event defined as a collection of actions needed to deliver a public service satisfying the needs of a citizen in a real-life situation is modelled using three kinds of ontology models represented in OWL to enable dynamic services integration.

Xiao et al. (2007) present yet another ontology-based approach for semantic interoperability in e-government; the business process of e-government services is described using an ontology model namely e-government business ontology, defined in OWL to enable the semantic interoperability of different government systems.

As raised earlier in this study, none of the above related studies has focused on the design and specification of a holistic and comprehensive methodology for the semantic-driven planning and implementation of e-government systems towards one-stop e-government portals. This study has overcome this weakness of previous research. In fact, the feature of maturity models, software engineering and Semantic Web domains are amalgamated to draw and specify a methodology framework as in Fig. 1 which provides structured guidelines (See sections 2.1, 2.2, and 2.3, and the business process model of the methodology framework in Fig. 5) for the planning and agile semantic-driven implementation of future e-government systems towards one-stop e-government portals. The next section presents additional support tools of the proposed methodology framework including alignment and weighting matrices as well as the limitations and future trends of the study.

6. Discussion

6.1. Alignment of maturity models stages with the phases of the proposed methodology framework

An analysis of the eleven maturity models presented in Fig. 6 reveals that nine (82%) of these maturity models suggest the integration of e-services at advanced stages of e-government development. However, none of the maturity models have suggested design guidelines that could help e-government developers to gradually and consistently prepare the integration of e-services from the lower stages of e-government growth. This study has overcome this weakness of existing e-government maturity models. The proposed methodology framework in Fig. 1 prescribes the semantic description and specification of e-services using various kinds of semantic ontology models at each phase of e-government development as a provision for future semantic integration and interoperability of e-services.

Although the maturity model stages layer (MMSL) of the proposed methodology framework has been illustrated with the United Nations maturity model stages as in Fig. 1, its alignment with other maturity models is feasible. From Fig. 6, one can see that the stages of maturity models share the same features (Cortes et al. 2006); for instance, at the first stage, all the maturity models, except the Asia Pacific (2004) model, require a static web presence and a one-way communication between government and citizens. Therefore, the first stage of these maturity models could be aligned in the framework similar to the first stage of the United Nation maturity model (see MMSL in Fig. 1). Similarly, Fig. 6 shows that at the second stage, the maturity models including Baum and Maio (2000), Chandler and Emanuel (2002), United Nations (2003), West (2000), Hiller and Blander (2001), Moon (2002), Deloitte and Touche (2001) required an enhanced web presence and two-way communication between government and citizens. The rest of the maturity models that encompass Layne and Lee (2001), Howard (2001), and World Bank (2003) prescribe a dynamic web presence and

on-line transaction at the second stage. Only the Asia Pacific (2004) maturity model is still at the state of static web presence and one-way communication at the second stage. Once again, the second stages of other maturity models could be aligned at the second phase of the proposed e-government application development framework, the same as the second stage of the United Nations maturity model at the MMSL in Fig. 1. Such similarities of e-government web features at different stages of maturity models (Cortes et al. 2006) is found in Fig. 6; based on this, we have drawn in Table 4 the alignment matrix of the maturity models stages with the three phases of the proposed e-government systems development methodology framework in see Fig. 1. An alignment matrix *AM* is formally defined as in equation (1) below.

$$AM(m, s) = \begin{cases} (x, y) \\ x \end{cases} \tag{1}$$

Where, *m* is a maturity model, *s* a stage of the maturity model *m* and $1 \leq s \leq 6$ in this study. In equation (1), *x* and *y* are the methodology framework’s phases to which *s* is aligned; then, as it is drawn in Fig. 1, a stage *s* of a maturity model *m* could be aligned either to 1 (*x* as in equation (1)) or 2 (*x* and *y* as in equation (1)) phases of the framework. In other words, the implementation of a web feature required by a maturity model stage *s* could start at the phase *x* and end at the phase *y* of the framework or it can simply start and end a phase *x*.

Table 4
Alignment matrix of maturity model stages with the methodology framework

Maturity Models	Maturity Model Stages					
	1	2	3	4	5	6
Alignment with Framework Phases						
United Nations (2003)	1,2	2,3	2,3	3	3	
Layne & Lee (2001)	1,2	2,3	3	3		
Baum & Maio (2000)	1,2	3	3	3		
Chandler & Emanuel (2002)	1,2	2,3	3	3		
West (2000)	1,2	2,3	3	3		
Hiller & Blanger (2001)	1,2	2,3	3	3		
Moon (2002)	1,2	2,3	3	3	3	
Asia Pacific (2004)	1	2	2,3	3	3	3
Deloitte & Touche (2001)	1,2	2,3	3	3	3	3
Howard (2001)	1,2	3	3			
World Bank (2003)	1,2	3	3			

In Table 4, the intersection of column 1 and the United Nations maturity model contains the couple (1, 2); meaning that, the first stage of the United Nations maturity model is aligned to both the first and the second phases of the proposed methodology framework; in other words, the stage starts at the first phase and ends at the second phase of the framework. Similarly, the intersection of column 3 and the Asia Pacific maturity model contains the couple (2, 3); meaning that, the third stage of the Asia Pacific maturity model is aligned to both the second and the third phases of the framework i.e., the third stage of the Asia

Pacific maturity model commences at the second phase and ends at the third phase of the framework.

From the fourth column, only the number 3 is appearing in the cells of Table 4; this signifies that, all the stages of maturity models from the fourth stage onward are aligned to the third phase of the framework which is the web services development phase. We can conclude that, although the maturity models studied in this research are of at most six stages, a maturity model with more than six stages will still be aligned conveniently to the framework phases. In fact, advanced stages will be aligned to the third phase of the framework, as the main activity at these stages is web services development.

6.2. Weighting of ontology activities at various phase of the proposed methodology framework

Based on the alignment Matrix in Table 4, we have constructed in Table 5 the weighting matrix of the framework phases and corresponding output ontologies with the maturity models stages. A weighting matrix *WM* is formally defined as in equation (2) below.

$$WM((x, y), s) = \begin{cases} 1 & (s \text{ is aligned to } x) \\ 0 & (s \text{ is not aligned to } x) \end{cases} \quad (2)$$

Where, *x* is a framework phase, *y* an ontology model prescribed at *x* and *s* a maturity model's stage. Equation (2) specifies that, an entry of the weighting matrix *WM* is either 1, if the stage *s* ($1 \leq s \leq 6$) of all the maturity models (11 maturity models used in this study as in Fig. 6 and Table 4) is aligned to the framework phase *x* ($1 \leq y \leq 3$) with ontology model *y* or 0, if the stage *s* of all the maturity models are not aligned to the *x* phase of the framework.

A digit 1 in a cell of Table 5 under the maturity model stages columns means that the corresponding stage of all the maturity models is aligned to the corresponding phase of the framework. The weight of a particular phase of the framework is then obtained as the number of stages that are aligned to it (see the rightmost column of Table 5). The weight of a phase can also be obtained from Table 4 by counting the number of columns containing the corresponding framework phase number (1, 2 or 3).

Table 5
Weighting matrix of the framework phases and maturity model stages

Framework Phases and Output Ontologies	Maturity Model Stages						Weight
	1	2	3	4	5	6	
Scope Definition, <i>Domain Ontology</i>	1						1
Identification and Categorization of Services, <i>Domain and Task Ontologies</i>	1	1	1				3
Web Services Development, <i>Representation or Meta Ontology</i>		1	1	1	1	1	5

Fig. 7 shows the chart of maturity models stages aligned to the methodology framework phases and corresponding output ontologies. Fig. 7 also shows that, the methodology framework recommends more practice of

semantic activities at the advanced phases of the methodology framework for easy services integration, maintenance, and interoperability. The percentages displayed in Fig. 7 represent the intensity of ontology activities at each phase of the proposed methodology framework.

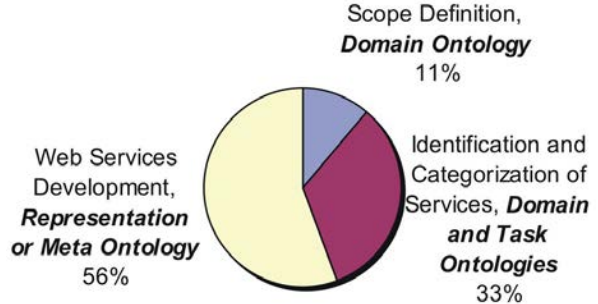


Fig. 7: Chart of the intensity of semantic activities per phase of the methodology framework

6.3. Limitations and future trends of the study

This study has presented a methodology framework for the semantic-driven development of future e-government systems. However, e-government development is not only about software or technology adoption; other issues including political, institutional, social, cultural, etc., may influence the application of the proposed framework in the e-government development context of a given country. Furthermore, despite its intensive empirical validation through parts and experimental studies presented at conferences (Fonou-Dombeu and Huisman 2010a, 2011a, 2011c, 2011d) and published in journals (Fonou-Dombeu and Huisman 2010b, 2011b, 2011e), the specification of the semantic content of the methodology framework has to be expanded to provide more insights on the mechanisms and algorithms for e-services integration, as well as the storage and query of semantic ontology models describing e-services during iterations, at various phases of development. This will be the focus of the next stage of research.

7. Conclusion

A methodology framework which provides stages, tools and techniques for the semantic-driven implementation of e-government systems at various phases of development was presented in this study. Due to the fact that the framework phases might not always be applied chronologically or in a linear order, its business process model was developed to enable the iterative and incremental development of e-government systems.

The proposed methodology framework provides directions for the software development of future e-government systems based on Semantic Web technologies which are emerging in the field of e-government and which have potential to facilitate the integration and interoperability of resulting e-government systems towards one-stop e-government portals. The technology oriented

nature of the framework makes it a useful tool to be used by e-government project teams in conjunction with political, cultural, institutional, legal, and social conditions of each specific country.

Finally, the study would particularly be of interest to e-government project teams of developing countries where little or no progress has been made towards the development of one-stop portals for seamless online services delivery to citizens.

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CHAPTER III

Paper 2:

Investigating e-Government Knowledge Base Ontology Supporting Development Projects Monitoring in Sub Saharan Africa

Investigating E-government Knowledge Base Ontology Supporting Development Projects Monitoring in Sub Saharan Africa

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Abstract

In recent years, a number of developed countries have employed ontology in e-government projects. On the other hand, Sub Saharan African (SSA) countries have followed the trends towards e-government and adoption of new technologies during the past eight years, resulting in many applications developed in various government departments. However, little work has been done in building knowledge base ontologies that facilitate communication amongst stakeholders and that specify processes and data description of these applications; thereby, guaranteeing their maintainability, interoperability and sustainability. This paper presents a case study of constructing ontology in support of e-government initiatives in the domain of development projects monitoring in a Sub Saharan African country. Case studies of development projects conducted in different SSA countries as well as related published works in various fields including project management, project monitoring and evaluation, and capacity building are reviewed and the features of the ontology are extracted. The main purposes of the ontology encompass; providing developers of potential e-government applications for development projects monitoring in Sub Saharan Africa and the developing world at large, with key concepts and activities of the domain, facilitating communication amongst all the role players involved in development projects implementation by providing a common and shared representation of concepts and activities of the domain, and serving as a knowledge base system to the monitoring and evaluation activities of development projects - thereby, strengthening efficiency, effective and sustainable implementation of development projects in Sub Saharan Africa. Further, the study aims at sensitizing and serving as a practical case study of building ontology in support of e-government adoption processes in Sub Saharan Africa.

Categories and Subject Descriptors: J.1 [**Computer Applications**]: General; D.2.10 [**Software Engineering**]: Design - *Methodologies; Representation*

Additional Key Words: E-government, Ontology, Knowledge Base System, Development Project, Protégé

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1. INTRODUCTION

The continuous improvement of Information and Communication Technologies (ICT) has drastically changed the way governments the world over, deliver services to citizens, businesses and organizations. The use of ICT for public services delivery is called electronic government (e-government). The ICT facilities and the Internet technologies are used to deploy web-based applications that support government processes. This support consists of: (1) providing a large range of government information and services (health care, education, social services, community development, taxes return, etc.) online, (2) facilitating online citizens' participation to government processes and decision making, and (3) streamlining and reorganizing government processes. Sub Saharan African (SSA) countries have followed the trends towards e-government and adoption of new technologies during the past eight years [Bwalya 2009; Kaaya 2004; Ngulube 2007]. Consequently, many applications have been and are currently being developed in various government's departments [Bwalya 2009; Kaaya 2004; Kitaw 2006; Shuppan 2009], aimed at providing better delivery of services to citizens, businesses and organizations. However, little work has been done in building knowledge base ontologies that facilitate communication amongst stakeholders and that specify processes and data description of these applications.

Jakachira et al. [2008] present a web-based e-government application that allows citizens from the Dwesa rural area in South Africa to access government services online; through the application, citizens from the Dwesa rural area can download, fill and send forms and reports electronically to the department of Home Affairs and the municipality respectively. The Zambia Health Management Information System (ZHMIS) and Immigration Management System (ZIMS) are presented by Bwalya [2009]; both systems are e-government applications that provide online services delivery in the health and immigration sectors. Shuppan [2009] presents three case studies of e-government applications implemented in Ghana, Tanzania and Kenya. In Ghana, the e-government application called GCNet allows all customs transactions related to the import and export of goods to be done electronically. The Tanzanian e-government application is an integrated tax management system (ITAX). Implemented with the support of the German Agency for Technical Cooperation (GTZ), the ITAX allows electronic collection of tax revenues all over Tanzania. In Kenya, the Business Keeper Monitoring System (BKMS) is an e-government application that allows anonymous online reporting of incidents of corruption. To facilitate anonymous reporting, the BKMS uses a secure website; this makes it possible for a whistleblower to communicate with the corruption investigators of private businesses or with the police without revealing his or her identity [Shuppan 2009]. Kaaya [2004] presents an analysis of the status of e-government services in three East Africa countries including Kenya, Tanzania and Uganda. The study has conducted the visibility and usability tests of government websites in the three countries and has concluded that all of the East Africa websites are at the first and second stages of e-government development. Three case studies of e-government initiatives carried out in Rwanda, Ethiopia and Mauritius are presented by Kitaw [2006]; the case studies were selected to illustrate the three e-government delivery models (government to citizens (G2C), government to government (G2G) and government to business (G2B)) in Sub Saharan Africa. The Rwanda case study illustrates the G2C model; it focuses on e-government applications which deliver secure web-based email service, online electronic forms for national identity document or passport and visa, as well as Public Internet Access Centers [Kitaw 2006]. The Ethiopian WeredaNET project have been selected to illustrate the G2G model; its aim was to build terrestrial and satellite-based network connecting lowest levels of government (federal, regional and local) and deliver the following services: video conferencing, Web services, Voice over IP, and electronic messaging [Kitaw 2006]. In Mauritius, the Contributions Network Project (CNP) illustrates a G2B e-government model; the CNP has developed an e-government application that allows electronic submission of returns, payment of taxes and contributions [Kitaw 2006].

Most of the above e-government applications currently run in SSA countries provides only one way interaction with citizens. They present government information in form of simple web pages and offer few online services to citizens and stakeholders. Government services delivered online mainly consist of downloading, filling and submitting forms to government departments; in many cases, the online submission is still unavailable and citizens have to visit government offices in order to submit their forms [Kaaya 2004; Ngulube 2007]. Largely, there is no structured database of government valuable information accessible interactively through these applications nor evidence of proper knowledge base systems that specify processes and data description of these applications; thereby, guaranteeing their maintainability, integration, interoperability and sustainability.

In this paper, we present a case study of constructing ontology in support of e-government initiatives in the domain of development projects monitoring in a Sub Saharan African country. The ontology presented here is not intended to provide a definitive and comprehensive account of the many aspects of development projects implementation, but it aims at serving as a foundation for further specification efforts. Case studies of development projects conducted in different SSA countries as well as related published works in various fields including project management, project monitoring and evaluation, and capacity building are reviewed and the features of the ontology are extracted. The main purposes of the ontology encompass: (1) providing developers of potential e-government applications for development projects monitoring in Sub Saharan Africa and the developing world at large, with key concepts and activities of the domain, (2) facilitating communication amongst all the role players involved in development projects implementation by providing a common and shared representation of concepts and activities of the domain, and (3) serving as a knowledge base system to the monitoring and evaluation activities of development projects; thereby, strengthening efficiency, effective and sustainable implementation of development projects in Sub Saharan Africa. Further, the study aims at sensitizing and serving as a practical case study of building ontology in support of e-government adoption processes in Sub Saharan Africa.

The rest of the paper is organized as follows. Section 2 defines ontology and describes its use in software engineering and e-government. The methodology we followed to gather information and to build the ontology is presented in section 3. Section 4 presents and discusses the results. A conclusion is drawn in the last section.

2. ONTOLOGY MODELING

2.1. Definition and Role of Ontology

There are several definitions of ontology in the literature [Gomez-Perez and Benjamins 1999]; the most common definition is taken from Gruber [1993]. Ontology is an explicit specification of a conceptualization. A conceptualization is an abstract and simplified view of a domain of knowledge we wish to represent for certain purposes; the domain could be explicitly and formally represented using existing objects, concepts, entities and the relationship that exists between them [Gruber 1993]. Ontology is widely used in disciplines such as software engineering, databases, artificial intelligence, and many more [Welty 2003]. In these fields, developers use ontology to represent knowledge in a way that can be automatically processed by a machine. In particular, the interest of ontology in software engineering is acknowledged by many authors. In [Ceccaroni and Kendall 2003; Usero and Orenes 2005] the authors argued that ontology represents the concepts of a domain of knowledge and the relationships between them, which provide a shared and common understanding of the structure of information among people and software agents, thereby facilitating software development and improving processes in the corresponding domain. Aside the semantic representation of concepts of a domain of knowledge, ontology also provides data type description which specifies the data component of applications [Bettahar et al. 2005]. Ontologies are application independent; which allow domain knowledge reuse and easy software maintenance, and contributes to the semantic interoperability of applications [Gruber 1993]. The complexity of government processes along with the increasing number of applications that are implemented in various government departments, need ontologies to streamline and re-organize government services and facilitate their integration, maintenance and interoperability [Bettahar et al. 2005; Mondorf and Herborn 2008]. The above works demonstrate the usefulness of ontology in e-government processes and particularly for e-services integration. Some practices of ontology in e-government are described in the next section.

2.2. Practices of Ontology in E-government

A number of countries employ ontology in e-government projects [Ralf 2003; Bettahar et al. 2005]. The OntoGov project which aims at developing an ontology platform that facilitates the consistent configuration and re-configuration of e-government services is presented by Apostolou et al. [2005]. Bettahar et al. [2005] describe a methodology for building ontology in the social care domain within the context of e-government. Gomez-Perez et al. [2006a] present an ontology-based model for efficient and fast retrieval of government documentation; they further introduce a set of legal ontologies for the transaction domain in e-government [Gomez-Perez et al. 2006b]. Ortiz-Rodriguez [2006] uses a set of government ontologies to represent Mexican local government processes. An ontology-based fraud detection system for e-government is presented by Alexopoulos et al. [2008]. Herborn and Wimmer [2004] present an ontology

driven semantic for business registers; which aims at facilitating business transactions amongst companies across European Union countries. Salhofer et al. [2009] present an approach of using ontology for services integration in e-government; the approach consists of building ontology at the start of an e-government project and uses the resulting ontology as a domain model for generation of application services. A so called goals/desires approach was employed to illustrate how e-services could be derived from goals predefined in form of simple sentences or phrases. A method of automatic ontology mapping is presented by Chen et al. [2008]; a Semantic Service Agency (SSA) is designed for each government department; each SSA is a domain ontology which has a department portal and supply to the citizen the whole set of available services or a part of the services; a Semantic Integrating Model is employed to integrate all the SSA; ontology mapping is achieved using semantic similarity techniques. The next section presents the ontology modeling approaches.

2.3. Ontology Modeling Approaches

Several methodology approaches for building ontology have been proposed in the literature [Fernandez-Lopez 1999; Beck and Pinto 2003; Calero et al. 2006]. These approaches recommend different steps and tasks that must be performed when building ontology. However, there is still no standard method for building ontology. The approach described in this research was adopted from the Uschold and King [Fernandez-Lopez 1999, Calero et al. 2006] ontology modeling approach. Further, a new ontology could be constructed from existing ontologies or from scratch [Calero et al. 2006]; we have adopted the later as our domain of interest. It was not aligned to any existing ontology domains. The methodology we used to gather information and construct the ontology is presented in the next section.

3. METHODOLOGY

3.1. Data Collection

We gathered concepts and activities of the domain by: reviewing case studies of development projects implemented in Sub Saharan Africa, interviewing municipalities' and non-governmental organizations' employees, and academic members, and reviewing related published and working papers in various fields including project management, project monitoring and evaluation, and capacity building.

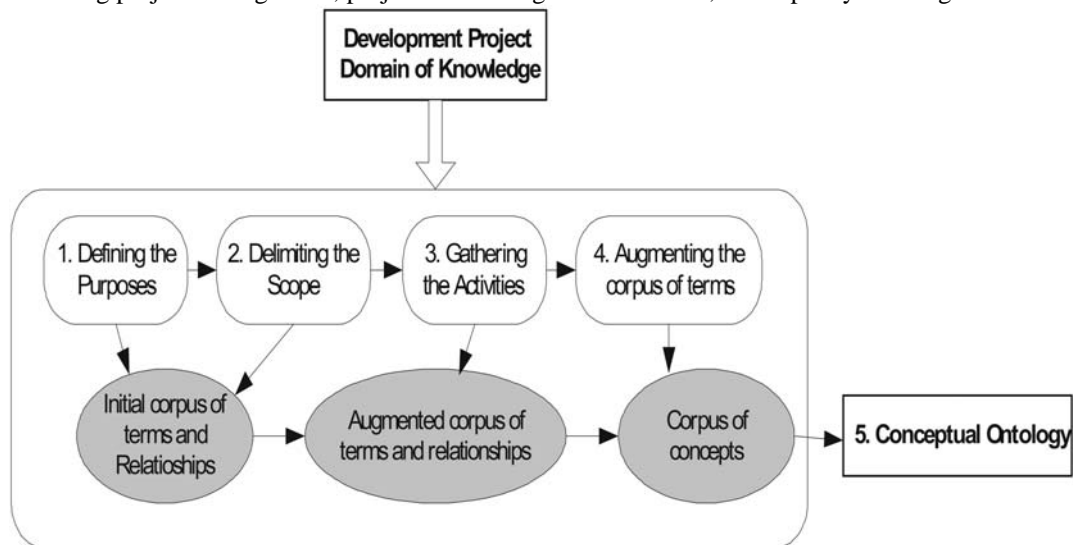


Figure 1: Framework of the Ontology Building Process

3.2. Framework for Building the Ontology

We followed five steps in building the ontology. Figure 1 shows the framework of the ontology building process.

3.2.1. Purposes of the Ontology

The purposes of the ontology were deduced from the analysis of the role and the current state of impact of development projects in Sub Saharan Africa. Clearly speaking, Sub Saharan African governments use

development projects as tools for providing solutions to problems facing their people. However, the number of actors involved including government, donors, non-governmental organization (NGO), private companies, civil society, academic institutions and communities, makes development projects implementation a complex task; furthermore, other human factors such as corruption, incompetence, weak monitoring and evaluation have led to poor performance of development projects in Sub Saharan Africa since many decades of multiple aids from national and international aids agencies, government and non-governmental organizations [Copson 2006; Okereke 2007]. Then, in this era of e-government adoption in Sub Saharan Africa [Kaaya 2004; Ngulube 2007], we believe that it is important to look at building consistent knowledge base systems as ontologies to support potential e-government initiatives towards effective monitoring and evaluation mechanisms of projects, for efficient, effective, transparent and sustainable implementation of development projects in Sub Saharan Africa.

3.2. 2. *Scope of the Ontology*

The scope of the ontology was delimited by analyzing the life cycle of a development project and the activities that are carried out during various phases. According to the works in [Quarthey 1996; Ahsan and Gunawan 2009] the life cycle of a development project can be broadly broken into three main phases including planning, implementation and evaluation. In our research, we assume that development projects have been designed and planned conveniently and that all the role players are known. Our work focuses on the implementation phase of projects i.e. the phase of the real delivery to people. The resulting ontology will then serve as a knowledge base system to the monitoring and evaluation activities of projects; thereby strengthening efficiency and effective delivery to communities.

3.2. 3. *Activities of the Domain*

The two previous steps of the framework provided the first corpus of terms of the domain including potential role players involved in the implementation phase of development projects (government, donors, NGO, private companies, civil society, academic institutions, and communities). Further, we gathered the activities of the domain by reviewing case studies of development projects implemented in Sub Saharan Africa and interviewing six municipalities' and NGO's employees and three academic members. The interviews with municipalities' and NGO's employees were scheduled at specific periods of time and took about twenty five to thirty minutes each, whereas interviews with academic members were done in form of regular discussions about the subject, for almost an hour each. The case studies reviewed were selected based on their level of details in describing the activities of development projects implementation. Table 1 presents selected development projects that we have reviewed.

Table 1: Selected Case Studies of Development Projects in SSA

Project	Country of Implementation	Financier	Development Sectors
Participatory Design of a Community-Based Child Health Information System in South Africa (http://www.egov4dev.org/health/case/childhealthis.shtml)	South Africa	- South Africa Government - UK Department for International Development	Health Care
Ghana Agricultural Information Network System (GAINS) (http://www.ciard.net/index.php?id=580)	Ghana	- Government - World Bank - International Institute of communication and Development (IICD)	Agriculture and Rural development
Integrated Urban Housing Project (IUHP) (http://practicalaction.org/?id=iuhd_working_papers)	Kenya	- United Kingdom Department for International Development (DFID)	Housing
The Women's Information Resource Electronic Service (WIRES) (http://www.bridges.org/case_studies/135)	Uganda	- International Development Research Centre (IDRC) (http://www.idrc.ca/) - World Bank - Hivos	Information and Communication Technology (ICT)
Integrated Development project with the "Wa Nyè U Saalu Zie" Union (http://www.fao.org/sd/erp/Celim.pdf)	Burkina Faso	- Celim Bergamo (Non-Governmental Organization)	Social, Health and Agriculture

The case studies and project reports we reviewed do not provide information on activities related to the finance and the monitoring indicators of development projects implementation. Then, we conducted interviews and investigated related published and working papers in various fields including project

management, project monitoring and evaluation, and capacity building [Ahsan and Gunawan 2009; Bergeron et al. 2006; Crawford and Bryce 2003; Goldman et al. 2006; Mosse and Sontheimer 1996; Quarley 1996; World Bank 1996]. The subject content of the papers reviewed, with regard to development projects monitoring activities, has motivated their choice in this research. This step produced an augmented corpus of terms and the relationships between them.

3.2. 4. *Improving the Corpus of Terms of the Ontology*

The corpus of terms obtained from the previous steps may not be complete enough to satisfy the purposes of the ontology. Then, the actual corpus has to be improved [Bettahar et al. 2005]. Our approach consisted of building a set of questions which needed to be answered by the ontology in order to fulfil its purposes; this process has added a set of new terms in the corpus. The concepts of the ontology are terms that define the domain or activities carried out in the domain [Bettahar et al. 2005]. Finally, we represented the conceptual version of the ontology as in Figure 2.

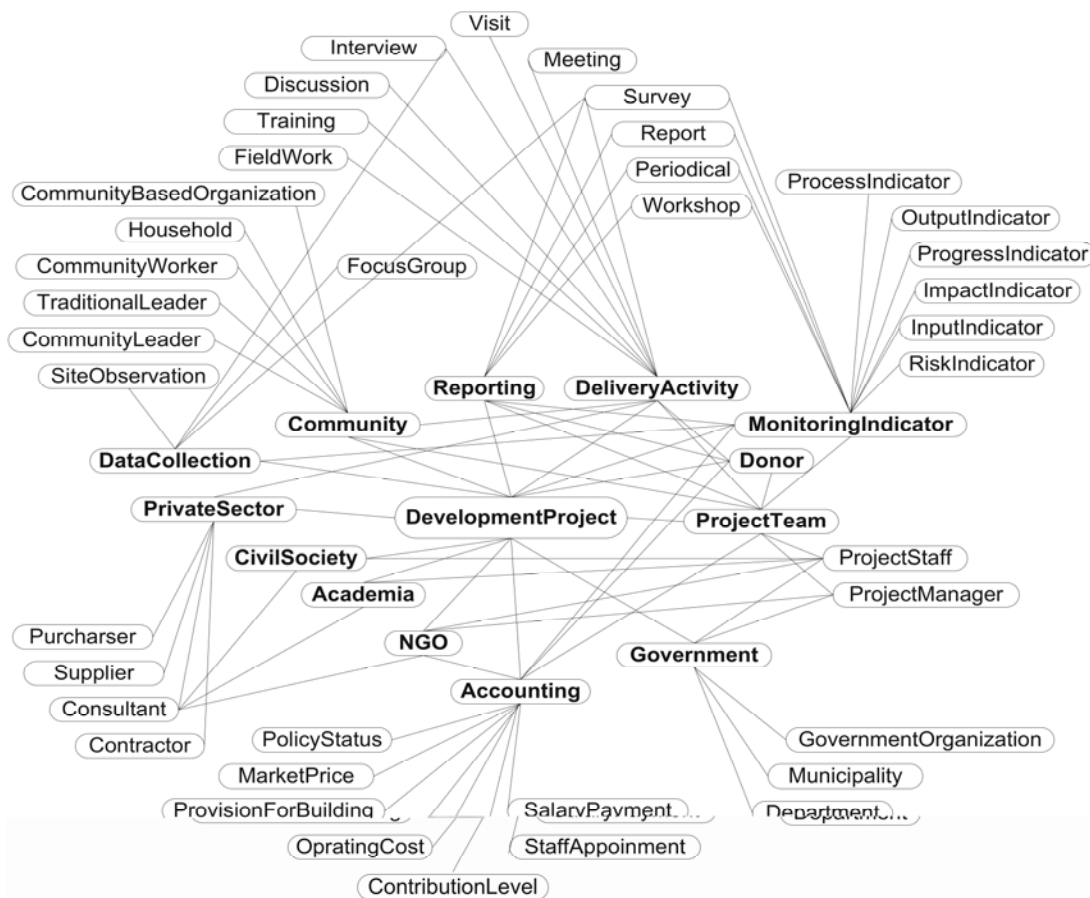


Figure 2: **Conceptual Representation of the Ontology**

4. RESULTS AND DISCUSSIONS

We have represented in Figure 2 the domain ontology of concepts and activities of development projects monitoring in a SSA country. Further, we used the ontology knowledge base editor Protégé to create the ontology. A screenshot of the Protégé version of the ontology is presented in Figure 3.

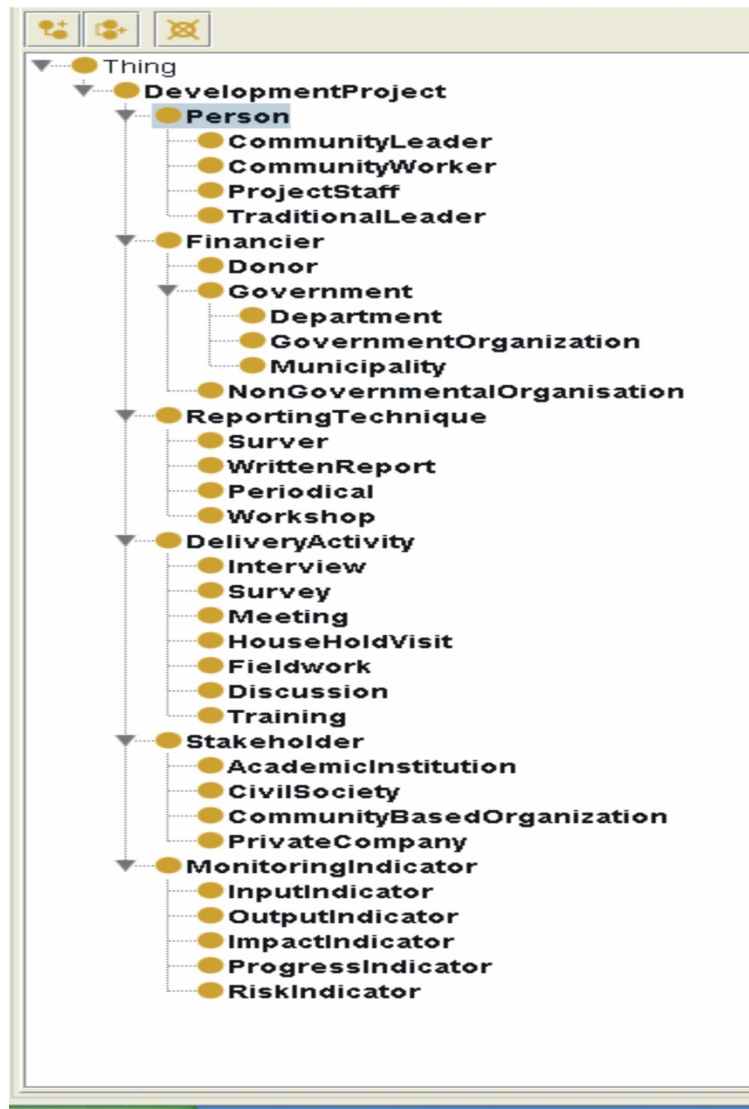


Figure 3: Protégé Version of the Ontology

From Figure 2, one can see that the ontology provides sufficient information about development projects implementation, to be able to facilitate communication between actors involved. For instance, the ontology shows that the level of impact of a project on a given community could be obtained by conducting a survey to get output indicators that represent the needed information.

The ontology aimed at serving as a knowledge base system to the monitoring and evaluation activities of development projects; to fulfil that goal it should be used as a data component of potential web-based e-government applications related to development projects implementation. These applications should provide the target users who are amongst others; government authorities, civil servants, donor organizations' and NGOs' employees, project staff, and communities, with appropriate and user-specific interfaces so that they can either update or query the knowledge base ontology. For instance, citizens could query the ontology to find out which are the development projects being run in their locality and who are the stakeholders involved. Similarly, a donor organization could query the ontology to get information on how far a particular development project has been implemented, in order to make decisions. A government authority could query the ontology to get the level of satisfaction of a community on the implementation of a particular project or get the level of contribution from the donors. Project staff could use appropriate interfaces to save statistical information as monitoring indicators in the knowledge base ontology.

5. CONCLUSION

This study demonstrates that ontology is useful in the e-government development processes as it provides a common and shared representation of concepts and activities of a domain of knowledge; thereby, allowing easy communication between stakeholders and facilitating integration, maintenance and interoperability of applications.

The literature discloses that many e-government projects in developed countries use ontology for data type description and web service features, and that the current e-government applications that are being run in SSA countries lack knowledge base components as ontologies that support their sustainability. We believe that this situation is in part due to the little academic debate on the subject in Sub Saharan Africa and the lack of proper protocols of collaboration between industries, governments and current research efforts towards promoting ICT and e-government in the continent.

The study examines case studies of development projects implemented in Sub Saharan African countries and reveals that many actors are involved in development projects implementation including government, NGOs, civil society, private sector, academia, donors and communities. The development project's activities are managed, monitored and coordinated by the project management team which must define specific indicators to monitor the activities. The project team deliver services to communities through community workers, community-based organizations, community leaders, traditional leaders, providers, suppliers, and households. The activities carried out during the delivery depend on the type of project (infrastructure development, water supply and sanitation, education, healthcare, etc.) and include: fieldwork, training, group reflection, discussions, interviews, surveys, meetings, and field visits. The data is collected during the delivery by means of site observation, focus groups, interviews and surveys. Finally, feedback is given to donors and stakeholders through regular reports or periodicals, and workshops. Given the importance of the development projects to SSA countries and the developing world at large, the above information would be certainly valuable to new researchers interested in the field in the future.

A case study of constructing ontology in support of e-government adoption processes in Sub Saharan Africa was carried out in the study. It uses a five step framework to methodically gather concepts and activities of the domain and to build the ontology. The complexity of the domain as well as the techniques employed to gather the ontology's features make it an added value to the ontology modelling body of knowledge. Overall, the study is aimed at raising the awareness of governments and e-government application developers from SSA countries and the developing world at large on the role of ontology in sustainable e-government development processes. In the near future, it would be valuable if European countries which are more experienced on the use of ontology in e-government projects enter into partnerships with African governments in order to strengthen the use of ontology in Sub Saharan African e-government projects.

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CHAPTER IV

Paper 3:

Semantic-Driven e-Government: Application of Uschold and King Ontology Building Methodology for Semantic Ontology Models Development

Semantic-Driven e-Government: Application of Uschold and King Ontology Building Methodology for Semantic Ontology Models Development

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ABSTRACT

Electronic government (e-government) has been one of the most active areas of ontology development during the past six years. In e-government, ontologies are being used to describe and specify e-government services (e-services) because they enable easy composition, matching, mapping and merging of various e-government services. More importantly, they also facilitate the semantic integration and interoperability of e-government services. However, it is still unclear in the current literature how an existing ontology building methodology can be applied to develop semantic ontology models in a government service domain. In this paper the Uschold and King ontology building methodology is applied to develop semantic ontology models in a government service domain. Firstly, the Uschold and King methodology is presented, discussed and applied to build a government domain ontology. Secondly, the domain ontology is evaluated for semantic consistency using its semi-formal representation in Description Logic. Thirdly, an alignment of the domain ontology with the Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE) upper level ontology is drawn to allow its wider visibility and facilitate its integration with existing metadata standard. Finally, the domain ontology is formally written in Web Ontology Language (OWL) to enable its automatic processing by computers. The study aims to provide direction for the application of existing ontology building methodologies in the Semantic Web development processes of e-government domain specific ontology models; which would enable their repeatability in other e-government projects and strengthen the adoption of semantic technologies in e-government. The research would be of interest to e-government system developers as well as the Semantic Web community, as the framework and techniques employed to develop the semantic ontology models might be repeated in other domains of knowledge to build ontologies.

KEYWORDS

E-government, Semantic Web, Ontology, Ontology Building Methodologies, Description Logic, Development Projects, OWL, Protégé.

1. INTRODUCTION

During the past six years, electronic government (e-government) has been one of the most active areas of ontology development [1], [2], [3], [4], [5], [6], [7]. In e-government, ontologies are

being used to describe and specify e-government services (e-services), primarily because they facilitate the semantic integration and interoperability of e-services.

Various different aspects of e-government have been modeled by researchers using the ontology paradigm. For example, Sanati and Lu [6] focus on the integration of e-services while the issue of composition, reconfiguration and evaluation of e-services was addressed by the ONTOGOV project [1], [2]. Other solutions for services integration were proposed in Chen et al. [8] and Gugliotta et al. [9]. Chen et al. [8] proposed a framework for services integration based on specific ontologies, whereas, Gugliotta et al. [9] established the mapping of various ontologies to a predefined e-government system reference model, with the purpose of achieving services integration and interoperability for one-stop portals. The issue of services interoperability is also addressed in [3], [7] and [10] with e-government specific ontology models. Another relevant literature by Puustjarvi [11] proposes a process-document ontology model for the business process modeling in e-government. The Reimdoc project [30] uses various ontologies to model the real-estate transactions.

Most of the aforementioned researches did not state whether any existing ontology building methodology was utilized in the development of their e-government domain specific ontology models. Furthermore, none of these studies employed a framework or an algorithm to show the step by step application of an existing ontology building methodology in a real world e-government service domain. Consequently, it is not clear in these previous works how an e-government system developer without any knowledge of ontology and Semantic Web technologies can repeat these proposed semantic e-government domain specific ontology models in other e-government projects, nor how to develop a solution for a complex public administration system. This oversight hinders the adoption of semantic technologies in e-government.

In this research the Uschold and King [12] ontology building methodology is applied to develop a government domain ontology as an improvement of the work in [13]. In [13], a qualitative data collection technique based on interviews and literature review was employed to gather the business requirements of a government service domain and a framework adopted from the Uschold and King [12] ontology building methodology was applied to construct a government domain ontology. The resulting domain ontology was used in [28] to conduct a case study of Semantic Web development of e-government domain ontology. This previous work is significantly improved in this research. In fact, the framework employed in [13] is revisited and emphases are placed on the detailed description and application of the Uschold and King [12] methodology. The domain ontology developed in [13] is further written semi-formally in Description Logic and validated for semantic consistency. The semi-formal ontology is also coded in OWL to enable its computer processing. Finally, the domain ontology is aligned to the DOLCE upper level ontology to allow its wider visibility and facilitate its integration with existing metadata standard.

The study aims to provide direction for the application of existing ontology building methodologies in the Semantic Web development process of e-government domain specific ontology models; which would enable their repeatability in other e-government projects and strengthen the adoption of semantic technologies in e-government. The research would be of interest to e-government system developers as well as the Semantic Web community, because the framework and techniques we employed to develop the semantic ontology models can be repeated in other domains of knowledge to build ontologies.

The rest of the paper is organized as follows. Section 2 presents the existing ontology building methodologies, the framework employed in this study to build the government domain ontology

as well as a case study of its application. Section 3 conducts a discussion and a conclusion is drawn in the last section.

2. METHODOLOGY

2.1 Ontology Building Methodologies

The commonly used definition of ontology is that proposed by Gruber [14] which states that ontology is an explicit specification of a conceptualization. A conceptualization refers to an abstract and simplified view of a domain of knowledge such as medicine, geology, geographic information system, e-government etc., to be represented for a certain purpose. The domain could be explicitly and formally represented using existing concepts, objects, entities and the relationships that exist between them [14]. Ontologies are widely used in various disciplines including computer science, software engineering, databases and artificial intelligence [15], [16]. In these fields, system developers use an ontology to represent knowledge in a machine processable format to enable their semantic processing by computers.

Several methodologies for building ontology have been proposed in the literature. Detailed comparative analyses of these methodologies are provided in [15], [17], [18]. These methodologies vary in the steps and tasks that they propose a practitioner should perform when building an ontology. There is still no standard method for building ontology. The methodology described in this research follows that of Uschold and King [12]. This methodology was chosen for its clarity and the fact that it is technology and platform independent [17]. The benefit of this methodology is that it is more likely to be understood by novice ontology developers and that it promotes a quicker development of the domain ontology. Furthermore, a new ontology can be constructed from scratch or from existing ontologies [15]. Following the recommendation of Uschold and King [12], a mixture of both approaches has been adopted in this study in the sense that on the one hand completely new domain ontology is constructed, and on the other hand, an alignment of the constructed ontology with the DOLCE upper level ontology [19] is provided. The next section presents the framework for building the government domain ontology.

2.2 Framework for Building the Ontology

Uschold and King [12] prescribed five stages for ontology development namely: identify the purpose, building the ontology, evaluation and documentation. In this research the first stage (identify the purpose) is split into two stages: define the purpose as well as the scope of the ontology. In the e-government domain it is important to also delimit the scope and coverage of the desired ontology as a government service for which ontology is being developed may be related to other services within the same department or across other departments. In their work, Uschold and King [12] have further divided the second stage (building the ontology) into three sub-stages namely: ontology capture, ontology coding, and integrating existing ontologies. However, no detailed guidelines are provided on how to gather the concepts and how to determine the relationships between the concepts, "only very vague guidelines relying on brainstorming techniques are given" [17]. In this research the concepts are gathered and the relationships of the domain ontology constructed using a qualitative approach with interviews and a literature review. The domain ontology is coded in a semi-formal representation using Description Logic. The semi-formal ontology is further coded formally in OWL to enable its automatic processing by computers. The second stage of the Uschold and King [12] method is completed by aligning the domain ontology to the DOLCE upper level ontology [19]. The third stage of the Uschold and King [12] method (evaluation) is performed by identifying and fixing semantic inconsistency in the domain ontology. The documentation stage of the Uschold and King [12] method is not executed in this paper because it either does not contribute directly in the building of ontology models which is the main purpose of this study nor does it affect the

previous stages used to build the ontology models. Further information on the documentation stage can be found in Uschold and King [12].

Fig. 1 presents the framework used in this study to apply the stages of the Uschold and King [12] methodology presented above in a development projects (DPs) monitoring service domain in Sub Saharan Africa (SSA) and the developing countries at large. Some selected DPs in SSA are provided in Table 1.

2.3 Case Study

In this section, the motivation for the case study is presented and the framework in Fig. 1 is applied to develop semantic ontology models including informal/conceptual/domain, semi-formal and formal ontologies.

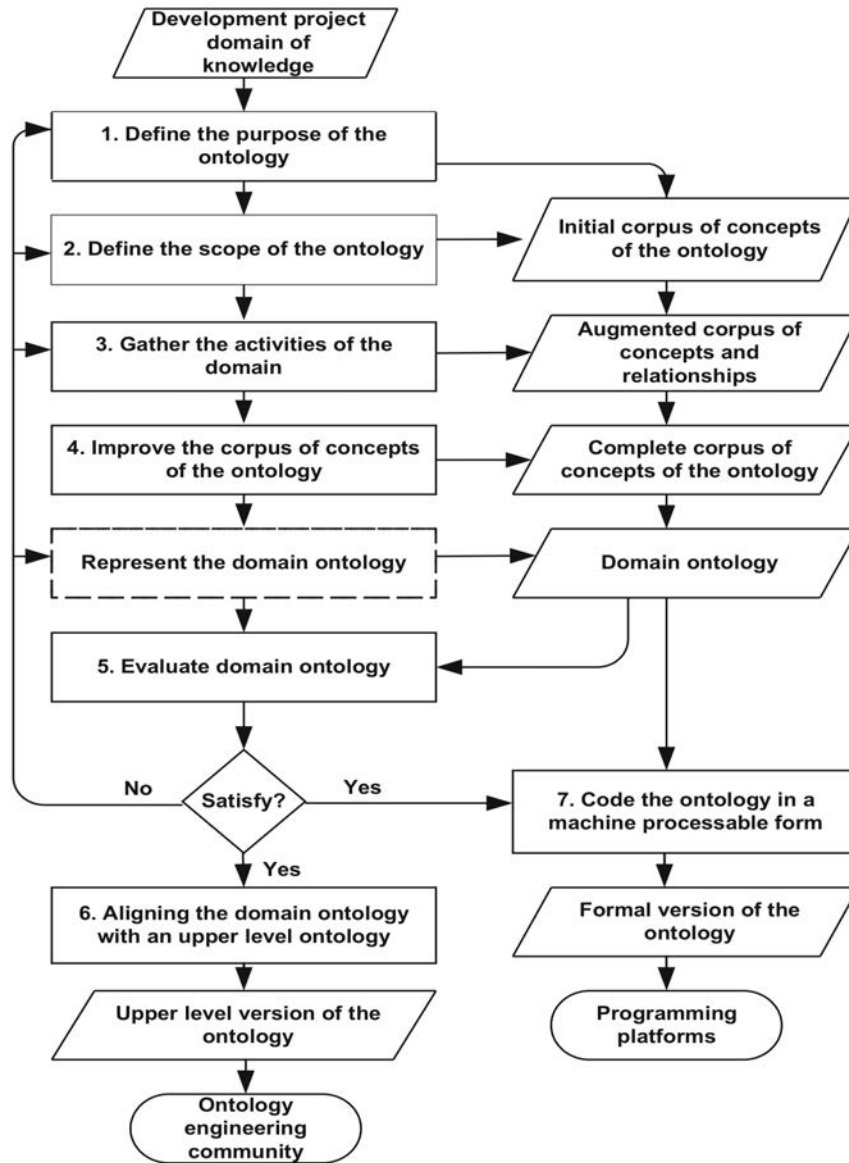


Figure 1: Framework of the ontology building process

2.3.1 Motivation

The case study used in this paper is an improved version of the work in Fonou-Dombeu and Huisman [13]. The motivation of the study comes from the fact that, in developing countries and in SSA in particular, almost every government department is somehow involved in the implementation of a programme aiming at improving the welfare of people. These programmes are commonly called development projects (DPs) and include infrastructure development, water supply and sanitation, education, rural development, health care, ICT infrastructure development and so forth. Thus, an e-government web application that could interface all the activities related to DPs implementation in a SSA country would bring tremendous advantages; particularly, such a web application would improve the monitoring and evaluation of DPs and provide transparency, efficiency and better delivery to populations. In Fonou-Dombeu and Huisman [13], an ontology support model for such a web-based e-government application was proposed and used in [28] to conduct a case study of Semantic Web development of e-government domain ontology. This study is a considerable improvement of this previous work. The methodology employed in Fonou-Dombeu and Huisman [13] is revisited and emphases are put on the detailed description and application of the Uschold and King [12] ontology building methodology. Additionally, (1) a set of competency questions are formulated and used to improve the corpus of concepts of the domain ontology, (2) the domain ontology is evaluated for semantic consistency using the Description Logic representation, (3) the domain ontology is further aligned to the DOLCE upper level ontology [19] to allow its wider visibility and facilitate its integration with existing metadata standard [9] and finally, (4) the domain ontology is formally represented in OWL to enable its automatic processing by computers.

As mentioned previously, the framework in Fig. 1 is an extension of the framework used in Fonou-Dombeu and Huisman [13]. Therefore, the first three steps of the framework namely, define the purpose of the ontology, define the scope of the ontology and gather the activities of the domain, are identical and will not be repeated in this research; detailed description of these three first steps are provided in Fonou-Dombeu and Huisman [13]. In summary, in these three first steps, the purposes of the ontology was deduced by analyzing the roles and the current state of impact of DPs in SSA; the scope of the ontology was delimited by analyzing the life cycle of a development project (DP) and the activities that are carried out during various phases. Then, the research was focused on the implementation phase of DPs, which is the phase of the real delivery to people. The activities of the domain were gathered by evaluating case studies of development projects implementation (examples are provided in Table 1), interviewing domain experts including municipalities and non-governmental organizations' (NGO) employees and academic members, and reviewing publications in related fields including project management, project monitoring and evaluation, and capacity building [13]. In light of the above, the following subsections describe the remaining steps of the framework in Fig. 1, from the fourth step till the end.

Table 1: Selected case studies of development projects in SSA

Case Study No 1	
Project Name	The Women's Information Resource Electronic Service (WIRES)
Web Link	http://www.bridges.org/case_studies/135
Country	Uganda
Region	East Africa
Financiers	IDRC, World Bank, Hivos
Development Sector	Information and Communication technology (ICT)
Start Date	1999
Report Date	12 November 2003
Status at report date	At the second phase
Implementation	
Approach	Build telecentres to enable women access to ICT and the Internet
Key activities	<i>ICT training, meetings, seminars, workshops</i>
Monitoring and reporting	Formal monitoring every two months, a report after every six months
Participants	90 selected women, Network consultants, local leaders, community members
Case Study No 2	
Project Name	Participatory Design of a Community-Based Child health Information System in South Africa
Web Link	http://www.egov4dev.org/health/case/childhealthis.shtml
Country	South Africa
Region	Southern Africa
Financiers	<i>South African Government, UK Department of International Development</i>
Development Sector	Health care
Start Date	2000
Report Date	2004
Status at report date	<i>Satisfactory but was still at its infancy</i>
Implementation	
Approach	Monthly visit of community health workers to households for health data collection
Key activities	Household visits, training, interviews, focus group discussions, surveys, evaluation workshops
Monitoring and reporting	Regular village health days, use of observation forms during household visits, monthly summary forms for feedback reports
Participants	Community workers, traditional leaders, households, community members, municipalities, department of health, stakeholders (childhood practitioners, social workers, etc.)

2.3.2 Improving the Corpus of Concepts of the Ontology

During the first three steps of the framework in Fig. 1 presented above, the initial corpus of concepts of the domain is gathered. This corpus of concepts may not be complete enough to satisfy the purposes of the ontology. Therefore, the actual corpus has to be improved. This can be done by building a set of competency questions which need to be answered by the ontology in order to fulfil its purposes [20]. To this end, a Use Case Diagram (UCD) was designed to represent the interactions of a potential web-based e-government application interfacing the constructed ontology with its target users including project staffs, government authorities, donor organization members, stakeholders and community members. From the UCD, a set of 23 questions is constructed to be answered by the ontology, listed in Table 2. Further, the questions

were analysed to find out which concepts are needed in the ontology to enable the inference of appropriate answers to them. This process has added a set of new concepts in the corpus. Finally, the domain ontology of development projects monitoring (OntoDPM) in a SSA country and the developing countries at large is represented in Fig. 2.

It is worth noting that the OntoDPM in Fig. 2 is identical to its first version developed in Fonou-Dombeu and Huisman [13]. In fact, in this previous work, the competency questions were used without any explicit mention of them in the text nor any explanation on how they were constructed. The competency questions in Table 2 are further mapped to the concepts of the formal version of the OntoDPM domain ontology later in this study. In the next section, the domain ontology in Fig. 2 is validated to ensure its semantic consistency.

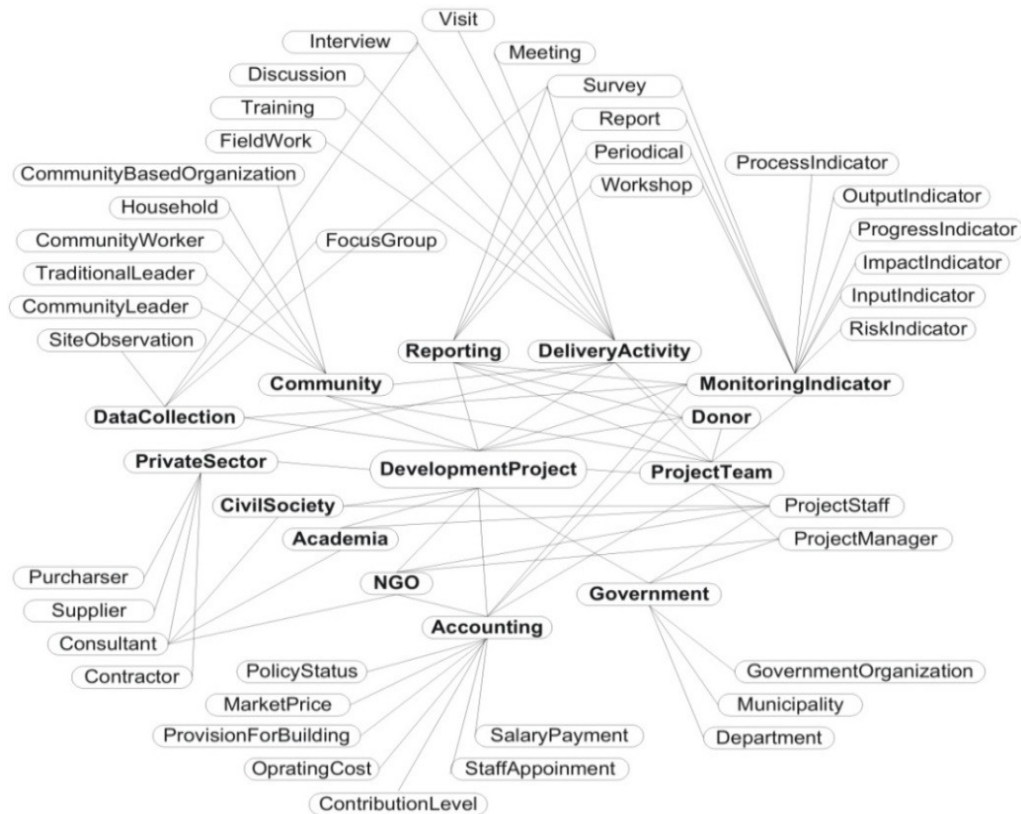


Figure 2: Domain ontology of development projects monitoring in a SSA country and the developing countries at large

2.3.3 Evaluate the domain ontology

The ontology engineering field prescribes three layers of ontology development [12]. From a form that can be understood by human beings to one that can be processed by computers, these ontology layers are: informal ontology, semi-formal ontology and formal ontology [12]. The domain ontology, like the one in Fig. 2, is the base ontology model for the development of the formal ontology that can be processed by computers. Therefore, it is important to evaluate its semantic consistency. This can be achieved by creating the semi-formal representation of the domain ontology in Fig. 2 using the Description Logic formalism. Care should then be taken to detect potential semantic inconsistency errors. A semantic inconsistency error is created when a class is wrongly classified as a subclass of another class; or when an instance is wrongly assigned

to a concept to which it does not really belong [21]. As drawn in the framework in Fig. 1, semantic inconsistency errors detected at this step can affect the initial graph structure of the domain ontology. Therefore, the ontology specialist should go back and readjust the domain ontology graph to remove the inconsistency errors; this might require a reanalysis of the initial steps applied to build the domain ontology as well (see Fig. 1).

Table 2: List of domain related questions to be answered by the ontology

Indexes	Questions
Q1	What are the current projects being run in a given locality?
Q2	What is the state of satisfaction of citizens on the implementation of a given DP?
Q3	Who are the stakeholders involved in a given DP?
Q4	Who are the financiers of a given DP?
Q5	Which government division is responsible for the implementation of a given DP?
Q6	What is the list of staff members of a given DP?
Q7	What is the expertise of a DP team member?
Q8	To which institution is a project team member affiliated?
Q9	What is the expertise of a private company involved in a DP?
Q10	What is the amount of contribution from each financier of a DP?
Q11	What is the contribution level of a financier of a DP?
Q12	What is the salary scale of project team members of a given DP?
Q13	What delivery activities are taking place in the day to day run of the DP?
Q14	What are the deadlines for accomplishment of each delivery activity?
Q15	What is the frequency of the delivery activities of DP?
Q16	What are the mechanisms or techniques for data collection during delivery?
Q17	What monitoring and evaluation techniques are used to assess the effectiveness of the implementation of a DP?
Q18	How frequently do the monitoring and evaluation operations take place?
Q19	Who are the actors in charge of the monitoring and evaluation of a DP?
Q20	What reporting techniques are employed to give feedback to top management?
Q21	What are the communication channels between a DP team member and the community?
Q22	Who are the representatives of communities in DPs?
Q23	What are the communication channels between the community and government?

Two formalisms are commonly used to represent a semi-formal ontology; they include UML class diagram [22] and Description Logic [21], [23]. The OntoDPM domain ontology was written semi-formally in UML in [28]. In this research, we have chosen the Description Logic formalism. The Description Logic representation of domain ontology is useful as it provides strong logical structure for the description and specification of domain knowledge [23], [24], facilitating the detection of semantic inconsistencies in domain ontology [21] and enabling semantic reasoning over the resulting ontology model. Furthermore, the OWL standard which is widely used in the field of Semantic Web is based on Description Logic [24].

Description Logic is a formal language for knowledge representation. Its syntax uses basic mathematical logic symbols such as subset, union, intersection, universal and existential quantifications, etc. to represent the relationships between the constituents of a domain. The

Description Logic version of the OntoDPM domain ontology in Fig. 1 is obtained by analysing its semantic and logical structures, identifying its classes, class hierarchy and class instances, and defining relationships between classes. The relationships include inheritance and association/composition relationships. A relationship is also called property or slot. Thereafter, the mathematical logic symbols mentioned above are used to represent the class hierarchy, relationships between classes (inheritance and properties), constraints on properties, etc. For instance, in the class hierarchy of the OntoDPM (see Fig. 2), community worker, community leader, traditional leader, and project staff are people (person class) involved in the development project implementation. Therefore, community worker, community leader, traditional leader, and project staff are subclasses of the person class, representing an inheritance relationship. This relationship is represented in Description Logic formalism using the subset and existential quantification symbols, and the isA property as follows:

$$\begin{aligned} \text{ProjectStaff} &\sqsubseteq \exists \text{ isA Person} \\ \text{CommunityWorker} &\sqsubseteq \exists \text{ isA Person} \\ \text{CommunityLeader} &\sqsubseteq \exists \text{ isA Person} \\ \text{TraditionalLeader} &\sqsubseteq \exists \text{ isA Person} \end{aligned}$$

The isA property represents the inheritance relationship between classes. Similarly, the class hierarchy of the OntoDPM shows that department, agency and municipality are division of government. This relationship between government and its divisions can be represented in Description Logic with a hasDivision property, the subset, existential quantification, and union symbols as follows:

$$\text{Government} \sqsubseteq \exists \text{ hasDivision.} (\text{Department} \cup \text{Agency} \cup \text{Municipality})$$

More information on the Description Logic syntax can be found in [21], [23]. Table 3, Table 4, and Table 5 present parts of the semi-formal representation of the OntoDPM domain ontology in Descriptive Logic. In particular, Table 4 and Table 5 represent the class hierarchy of the OntoDPM from which any semantic inconsistency errors have been removed. An alignment of the OntoDPM with the DOLCE upper level ontology is carried out in the next section as the step 6 of the framework in Fig. 1.

Table 3: Important axioms of concepts in the OntoDPM

DevelopmentProject \sqsubseteq Programme \sqcap \forall focuses Community
DevelopmentProject $\sqsubseteq \exists$ involves ≥ 1 (Person \sqcup Financier \sqcup Stakeholder \sqcup Community)
DevelopmentProject $\sqsubseteq \exists$ implements ≥ 1 DeliveryActivity
DevelopmentProject \sqsubseteq monitors ≥ 1 (MonitoringIndicator \sqcup Reporting \sqcup Accounting)
ProjectStaff \sqsubseteq Person $\sqcap \exists$ affiliates
$= 1$ (Municipality \vee Department \vee Agency \vee NGO \vee AcademicInstitution)
CommunityWorker \sqsubseteq Person $\sqcap \exists$ affiliates Municipality
CommunityLeader \sqsubseteq Person $\sqcap \exists$ resides Community
TraditionalLeader \sqsubseteq Person $\sqcap \exists$ resides Community
PrivateCompany $\sqsubseteq \exists$ delivers ≥ 1 DeliveryActivity
CommunityBasedOrganization \sqsubseteq owns Community
Donor \sqsubseteq Financier $\sqcap \forall$ hasContribution ContributionLevel

Table 4: Axioms of class hierarchy in the OntoDPM

DevelopmentProject	$\sqsubseteq \exists$ hasFunder. Financier
DevelopmentProject	$\sqsubseteq \exists$ hasCorporate. Stakeholder
DevelopmentProject	$\sqsubseteq \exists$ hasPeople. Person
DevelopmentProject	$\sqsubseteq \exists$ hasIndicator. MonitoringIndicator
DevelopmentProject	$\sqsubseteq \exists$ hasActivity. DeliveryActivity
DevelopmentProject	$\sqsubseteq \exists$ hasReport. ReportingTechnique
DevelopmentProject	$\sqsubseteq \exists$ hasData. DataCollectionTechnique
ProjectStaff	$\sqsubseteq \exists$ isA. Person
CommunityWorker	$\sqsubseteq \exists$ isA. Person
CommunityLeader	$\sqsubseteq \exists$ isA. Person
TraditionalLeader	$\sqsubseteq \exists$ isA. Person
Government	$\sqsubseteq \exists$ isA. Financier
Donor	$\sqsubseteq \exists$ isA. Financier
NGO	$\sqsubseteq \exists$ isA. Financier
PrivateCompany	$\sqsubseteq \exists$ isA. Stakeholder
AcademicInstitution	$\sqsubseteq \exists$ isA. Stakeholder
CommunityBaseOrganization	$\sqsubseteq \exists$ isA. Stakeholder
CivilSociety	$\sqsubseteq \exists$ isA. Stakeholder
Consultant	$\sqsubseteq \exists$ isA. PrivateCompany
Contractor	$\sqsubseteq \exists$ isA. PrivateCompany
Supplier	$\sqsubseteq \exists$ isA. PrivateCompany
Purchaser	$\sqsubseteq \exists$ isA. PrivateCompany
Government	$\sqsubseteq \exists$ hasDivision. (Department \sqcup Agency \sqcup Municipality)

Table 5: Axioms of class instances in the OntoDPM

MonitoringIndicator	$\sqsubseteq \exists$ IsIndividualOf. (InputIndicator \sqcup OutputIndicator \sqcup ImpactIndicator \sqcup ProcessIndicator \sqcup ProgressIndicator \sqcup RiskIndicator)
DeliveryActivity	$\sqsubseteq \exists$ IsIndividualOf. (Training \sqcup Discussion \sqcup FieldWork \sqcup HouseholdVisit \sqcup Meeting \sqcup Interview)
Reporting	$\sqsubseteq \exists$ IsIndividualOf. (Workshop \sqcup WrittenReport \sqcup Periodical)
DataCollection	$\sqsubseteq \exists$ IsIndividualOf. (Survey \sqcup SiteObservation \sqcup FOCUSGroup)

2.3.4 Alignment of the Domain Ontology with an Upper Level Ontology

A newly constructed domain ontology should not be kept in isolation; its concepts must further be aligned to those of generic upper level ontologies provided in the ontology engineering field. More information on these upper level ontologies could be found in [19], [25], [29]. This alignment will allow a wider visibility of the constructed domain ontology in the ontology engineering community and facilitate its integration with existing metadata standard [9]. In this research, the concepts of the OntoDPM have been aligned with the DOLCE upper level ontology [19]. Fig. 3 depicts the result of the alignment. The formal version of the OntoDPM is built in the next section and represents the last step (step 7) of the framework in Fig.1.

2.3.5 Code the Ontology in a Machine Processable Form

Semantic e-government entails using semantic ontology models to represent and describe government services in such a way that they can be automatically processed by computers. Therefore, the semi-formal version of the domain ontology (see examples in Table 3, Table 4 and Table 5) must be rewritten formally using an existing ontology representation language. The Semantic Web domain provides various languages for the formal representation of ontologies including Extensible Markup Language (XML), Resource Description Framework (RDF), DARPA Agent Markup Language (DAML), and OWL [26]. OWL is the most widely used of these languages because of its high expressive power and the fact that it is the W3C standard ontology language for the Semantic Web [27]. Several software tools are also used for ontology edition including WebODE, OntoEdit, KAON1, and Protégé [15]. Ontology developers prefer Protégé for its ease of use and its abstraction capabilities; it has a graphical user interface which enables ontology developers to concentrate on conceptual modeling without any knowledge of the syntax of the output language [27]. Furthermore, Protégé is open-source software which is downloadable from the Stanford Medical Informatics website.



Figure 3: Alignment of the OntoDPM with the DOLCE upper level ontology

In Fonou-Dombeu and Huisman [28], Protégé was used to create the OWL formal version of the OntoDPM domain ontology using its semi-formal representation in UML. In this research, the formal version of the OntoDPM in OWL is created with Protégé using the semi-formal specifications of its class hierarchy, relationships between classes and class instances written in Description Logic and validated for semantic consistency (see Table 3, Table 4 and Table 5). Several concepts including class, individual, slot, domain, range, etc. are employed in Protégé to create ontology. A slot is also called property and represents a relationship between classes. Each slot has a domain and a range, which are the classes involved in the relationship.

Once the ontology has been created with Protégé and saved as an OWL file onto the disc, it appears in the OWL syntax. The OWL syntax provides facilities for representing ontology elements such as inheritance, instance, slots, domain and range of a slot, etc. For instance in the OntoDPM, community worker, community leader, traditional leader, and project staff are subclasses of the person class (see Description Logic example in Table 4). This inheritance relationship is represented in OWL syntax with the following OWL code generated with Protégé.

```
<owl:Class rdf:about="#ProjectStaff">
  <rdfs:subClassOf rdf:resource="#Person"/>
</owl:Class>
<owl:Class rdf:about="#CommunityLeader">
  <rdfs:subClassOf rdf:resource="#Person"/>
</owl:Class>
<owl:Class rdf:about="#CommunityWorker">
  <rdfs:subClassOf rdf:resource="#Person"/>
</owl:Class>
<owl:Class rdf:about="#TraditionalLeader">
  <rdfs:subClassOf rdf:resource="#Person"/>
</owl:Class>
```

Similarly, in the OntoDPM, department, agency and municipality are divisions of government. The relationship between government and its divisions can be represented in Protégé with the slot hasDivision. Then, the domain of the hasDivision slot will be the government class and its ranges, the department, agency, and municipality classes. The hasDivision slot and its domain and ranges are represented in OWL with the following code generated with Protégé.

```
<owl:ObjectProperty rdf:about="#hasDivision">
  <rdfs:domain rdf:resource="#Government"/>
  <rdfs:range rdf:resource="#Agency"/>
  <rdfs:range rdf:resource="#Department"/>
  <rdfs:range rdf:resource="#Municipality"/>
</owl:ObjectProperty>
```

Parts of the OntoDPM properties, class hierarchy and class instances created with Protégé and imported with the programming editor JCreator are depicted in Fig. 4. In Fig. 4, it is shown each property (hasData, hasDivision, etc.) along with its domain and range(s), whereas, the inheritance relationships between classes are represented with the "subClassOf" property; class instances are indicated with the keyword "Thing".

3. DISCUSSION

This section (1) provides a short discussion on the use of OWL ontology in e-government (2) maps the competency questions in Table 2 with concepts of the formal version of the OntoloDPM domain ontology and (3) compares this study with related research.

3.1 OWL Ontology in e-Government

As mentioned earlier, OWL is a common language employed for semantic knowledge representation in e-government. In particular, OWL ontologies allow the composition [1], [7], searching, matching, mapping and merging [2], [6] of e-government services and facilitate their integration [1], [2], [5], maintenance [1] and interoperability [3], [4], [6], [7]. Therefore,

generating OWL ontology from a government service domain as it is done in this research and in [28] is an important step towards the development of Semantic Web applications as e-government applications, which have potential to perform semantic inference and reasoning over the OWL ontology and facilitate software components integration and interoperability. However, for the OWL ontology to be useful it has to be deployed in a real world application; this requires its storage and access through programming platforms. Future research will investigate the platforms for deploying OWL ontologies in real world applications including Java API, .NET, ASP, etc., as well as the database storage and query mechanisms of OWL ontologies. The mapping of the competency questions in Table 2 with the concepts of the formal version of the OntoDPM domain ontology is carried out in the next section.

3.2 Mapping of Competency Questions with Concepts of the Formal Ontology

In Section 2.3.2 the competency questions in Table 2 were analyzed to improve the corpus of concepts of the OntoDPM domain ontology in Fig. 2. Afterward, the concepts of the domain ontology were further analyzed to build classes, class instances, class hierarchy and properties between classes, for the formal representation (machine processable form) of the domain ontology; this process has added new concepts (e.g. person class) in the domain ontology as well as discarded some of them (e.g. project manager concept has simply become project staff). With all these changes in the transition from the human readable version of the domain ontology to the machine processable one, it is also important to map the competency questions to the concepts of the formal representation of the domain ontology; to ensure that answers to these questions would still be inferred from the ontology. In this section, a quantitative analysis is performed to establish the mapping of the competency questions in Table 2 to concepts of the formal version of the OntoDPM domain ontology. The formal version of the OntoDPM domain ontology is referred to from here on as formal ontology.

Part of OWL Representation of OntoDPM Properties

```
<owl:ObjectProperty rdf:about="#hasData">
  <rdfs:range rdf:resource="#DataCollectionTechnique"/>
  <rdfs:domain rdf:resource="#DevelopmentProject"/>
</owl:ObjectProperty>
<owl:ObjectProperty rdf:about="#hasDivision">
  <rdfs:domain rdf:resource="#Government"/>
  <rdfs:range rdf:resource="#Agency"/>
  <rdfs:range rdf:resource="#Department"/>
  <rdfs:range rdf:resource="#Municipality"/>
</owl:ObjectProperty>
<owl:ObjectProperty rdf:about="#hasFunder">
  <rdfs:domain rdf:resource="#DevelopmentProject"/>
  <rdfs:range rdf:resource="#Financier"/>
</owl:ObjectProperty>
<owl:ObjectProperty rdf:about="#hasIndicator">
  <rdfs:domain rdf:resource="#DevelopmentProject"/>
  <rdfs:range rdf:resource="#MonitoringIndicator"/>
</owl:ObjectProperty>
<owl:ObjectProperty rdf:about="#hasPeople">
  <rdfs:domain rdf:resource="#DevelopmentProject"/>
  <rdfs:range rdf:resource="#Person"/>
</owl:ObjectProperty>
<owl:ObjectProperty rdf:about="#hasReport">
  <rdfs:domain rdf:resource="#DevelopmentProject"/>
  <rdfs:range rdf:resource="#ReportingTechnique"/>
</owl:ObjectProperty>
```

Part of OWL Class Hierarchy of the OntoDPM

```
<owl:Class rdf:about="#Person"/>
<owl:Class rdf:about="#ProjectStaff">
  <rdfs:subClassOf rdf:resource="#Person"/>
</owl:Class>
<owl:Class rdf:about="#CommunityLeader">
  <rdfs:subClassOf rdf:resource="#Person"/>
</owl:Class>
<owl:Class rdf:about="#CommunityWorker">
  <rdfs:subClassOf rdf:resource="#Person"/>
</owl:Class>
<owl:Class rdf:about="#TraditionalLeader">
  <rdfs:subClassOf rdf:resource="#Person"/>
</owl:Class>
<owl:Class>
<owl:Class rdf:about="#Financier"/>
  <owl:Class rdf:about="#Donor">
    <rdfs:subClassOf rdf:resource="#Financier"/>
  </owl:Class>
</owl:Class>
<owl:Class rdf:about="#Government">
  <rdfs:subClassOf rdf:resource="#Financier"/>
</owl:Class>
<owl:Class rdf:about="#NGO">
  <rdfs:subClassOf rdf:resource="#Financier"/>
</owl:Class>
</owl:Class>
```

Part of OWL Class Instances of the OntoDPM

```

<owl:Thing rdf:about="#InputIndicator">
<rdf:type rdf:resource="#MonitoringIndicator"/>
</owl:Thing>
<owl:Thing rdf:about="#OutputIndicator">
<rdf:type rdf:resource="#MonitoringIndicator"/>
</owl:Thing>
<owl:Thing rdf:about="#ProcessIndicator">
<rdf:type rdf:resource="#MonitoringIndicator"/>
</owl:Thing>
<owl:Thing rdf:about="#ProgressIndicator">
<rdf:type rdf:resource="#MonitoringIndicator"/>
</owl:Thing>
<owl:Thing rdf:about="#RiskIndicator">
<rdf:type rdf:resource="#MonitoringIndicator"/>
</owl:Thing>
<owl:Thing rdf:about="#ImpactIndicator">
<rdf:type rdf:resource="#MonitoringIndicator"/>
</owl:Thing>

```

Figure 4: Part of OWL representation of OntoDPM domain ontology

Let Q and C be the sets of competency questions in Table 2 and concepts of the formal ontology respectively. The Semantic Relatedness Score (SRS) of a question Q_i , $1 \leq i \leq 23 \subseteq Q$ with concepts of the formal ontology noted SRS_{Q_i} , is defined as the number of concepts to which Q_i is semantically related to in the formal ontology. Mathematically SRS_{Q_i} is defined as in equation (1) below.

$$SRS_{Q_i} = \sum_{j=1}^n Card(c_j), 1 \leq j \leq n \quad (1)$$

Where, n is the number of main concepts to which Q_i is related to in the formal ontology and $Card(c_j)$ the number of instances of the concept $c_j \subseteq C$ in the formal ontology. The number $Card(c_j)$ is defined as in equation (2).

$$Card(c_j) = 1 + \sum Card(Instance(c_j)) \quad (2)$$

Where, $Instance(c_j) \subseteq C$ is an instance of the concept $c_j \subseteq C$ in the formal ontology. Furthermore, $Card(c) = 1$ if the concept $c \subseteq C$ is an instance or a concept which is a leaf in an inheritance hierarchy in the formal ontology.

As an example, let's consider the concept *government* in the domain ontology. The instances of *government* are *department*, *agency* and *municipality*. Based on equations (1) and (2) the SRS of a question $Q \subseteq Q$ which is semantically related to the *government* concept is computed as follows:

$$Card(government) = 1 + Card(department) + Card(agency) + Card(municipality) = 4$$

Similarly, a manual analysis of each competency question in Table 2 was performed and the main concepts of the development project (DP) domain which are semantically related to the question (see column 2 of Table 6) enumerated. For instance, let's consider the first question (Q1) in Table 2: "What are the current projects being run in a given locality?" The answer to this question relies on the information that would be provided by the municipality (concept which is semantically related to the word "locality" in the question Q1) as well as the development projects (concept which is semantically related to the word "projects" in the question Q1) under implementation in the municipality. As a result of the above analysis, it appears that the question Q1 in Table 2 is semantically related to the main concepts *development projects* and *municipality* in the development project domain (see column 2 of Table 6); in fact, the concepts *development projects* and *municipality* are synonyms of the words "locality" and "projects" respectively in the question Q1. This analysis was done independently of any knowledge of concepts of the formal ontology. A similar analysis was carried out for all the questions in Table 2 and the result is provided in the column 2 of Table 6.

Thereafter, the equation (1) and equation (2) were applied to compute the SRS of each question (see column 3 of Table 6). For instance, the column 2 of Table 6 shows that the competency question Q1 refers to the concepts *development projects* and *municipality* in the DP domain; both concepts are also concepts of the formal ontology. Furthermore, these concepts do not have any instances in the formal ontology class hierarchy; then, the SRS_{Q1} is 2 (see intersection of row 2 and columns 3 and 4 in Table 6). Similarly, column 2 of Table 6 shows that Q2 refers to concepts *community*, *development projects* and *monitoring indicator* in the DP domain. However, only *development projects* and *monitoring indicator* are also concepts in the formal ontology; in fact, the concept *community* has been discarded when building the semi-formal ontology. Furthermore, the concept *monitoring indicator* has six instances namely: output, input, process, progress, impact, and risk indicators, in the formal ontology (see the bottom part of Fig. 4). Then, the SRS_{Q2} is 8 (see intersection of row 3 and columns 3 and 4 in Table 6). As a result, the chart of the semantic relatedness scores of the competency questions in Table 2 with the concepts of the formal ontology is drawn in Fig. 5; it appears that each competency question is related to at least 2 concepts in the formal ontology. This indicates that the competency questions in Table 2 map the concepts of the formal ontology and that the developed domain ontology would be able to fulfill its purposes as defined at the early stage of its development. The next subsection compares this study with related works.

Table 6: Semantic relatedness score of competency questions with concepts of the formal Ontology

Q_i	c_i	$\sum Card(c_i)$	SRS_{Q_i}
Q1	DP, municipality	1+1	2
Q2	community, DP, monitoring indicator	0+1+(1+(1x6))	8
Q3	DP, stakeholder	1+(1+(1x4)+(1x4))	10
Q4	DP, financier	1+(1+(1x3)+(1x3))	8
Q5	department, municipality, agency, DP	1+1+1+1	4
Q6	DP, project staff	1+1	2
Q7	DP, project staff	1+1	2
Q8	project staff, government, NGO, private sector	1+(1+(1x3))+1+(1+(1x4))	11
Q9	DP, private sector	1+(1+(1x4))	6
Q10	financier, DP	1+(1x3)+(1x3)	7
Q11	contribution level, financier, DP	1+(1+(1x3)+(1x3))+1	9
Q12	salary payment, project staff, DP	1+1+1	3
Q13	delivery activity, DP	1+(1x7)+1	9
Q14	delivery activity, monitoring indicator, DP	1+(1x7)+(1+(1x6))+1	16
Q15	delivery activity, DP, monitoring indicator	1+(1x7)+1+(1+(1x6))	16
Q16	delivery activity, data collection	1+(1x7)+(1+(1x4))	13
Q17	monitoring indicator, DP	1+(1x6)+1	8
Q18	Monitoring indicator, DP	1+(1x6)+1	8
Q19	DP, monitoring indicator, project staff, private sector, community	1+(1+(1x6))+1+(1+(1x4)) + 0	14
Q20	reporting technique, DP,	1+(1x4)+1	6
Q21	DP, project staff, community leader	1+1+1	3
Q22	community leader, DP	1+1	2
Q23	community leader, government	1+(1+(1x3))	5

3.3 Comparison of this Study with Related Research

Table 7 and Fig. 6 draw a comparison of this research with related works. We have focused the comparison on the following criteria:

- Ontology building methodology: We are trying to find out if the research has disclosed the ontology building methodology employed.
- Framework or algorithm: Has the study designed or adopted a framework for the practical application of the ontology building methodology used (if there is any) in a government service domain.
- Level of specification: We seek to find out how detailed the specification of the proposed e-government domain specific ontology model in the study was.
- Implementation details: We are looking at the details of the implementation of the proposed e-government domain specific ontology models in terms of the Semantic web ontology languages and platforms employed, and whether a platform employed is open-source or proprietary.

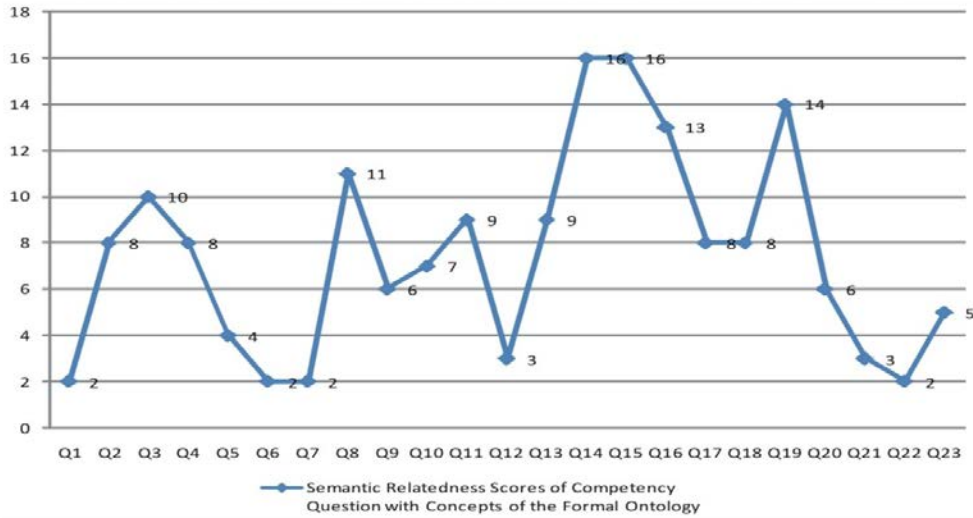


Figure 5: Chart of the mapping of competency questions with concepts of the formal ontology

Table 7: Comparative table of this study with related research

Authors	Ontology Building Methodology	Framework / Algorithm	Level of Specification	Implementation Details		
				Languages	Platform	Open / Proprietary
Sanati and Lu [6]	unreported	none	conceptual	none	none	
Apostolou et al. [1], [2]	unreported	none	conceptual	unreported	ONTOGOV	proprietary
Xiao et al. [3]	unreported	none	conceptual, formal	OWL	unreported	
Chen et al. [8]	unreported	none	conceptual	none	none	
(Our Work)	Uschold and King	adaptive framework	conceptual, semi-formal, formal	OWL	Protégé, Jcreator, JGrasp	open-source
Gugliotta et al. [9]	derived from DOLCE upper level ontology	none	conceptual, semi-formal	OCML	unreported	
Sabucedo and Rifon [10]	Methontology	none	semi-formal	none	none	
Sabucedo et al. [7]	unreported	none	semi-formal, formal	OWL	unreported	
Puustjani [11]	unreported	none	semi-formal	none	none	

In Table 7 and Fig. 6, it appears that only 3 (33%) researches out of 9, including this study have reported the ontology building methodology they have used to build the e-government domain specific ontology models. Furthermore, although Sabucedo and Rifon [10] and Gugliotta et al. [9] have disclosed the ontology building techniques they have used in their studies, little information is provided in these studies to explain how the methodologies can be applied to build the proposed ontology models for a complex public administration system. Similarly, amongst the 9 studies reported in Table 7, only 4 (44%) have reported the formal specification of the proposed e-government domain specific ontology models and programming codes in Semantic Web ontology languages. Table 6 shows that only this study has provided complete information for all the comparison criteria; most of the related works studied have reported their proposed e-government domain specific ontology models at the conceptual level only (78% in Fig. 6), with

little information provided on the ontology building methodologies employed and the implementation details. In Table 7, it is also shown that only this study has used a step-by-step framework adopted from an existing ontology building methodology to develop government domain ontology. Further information on the comparison criteria and results is depicted in Fig. 6.

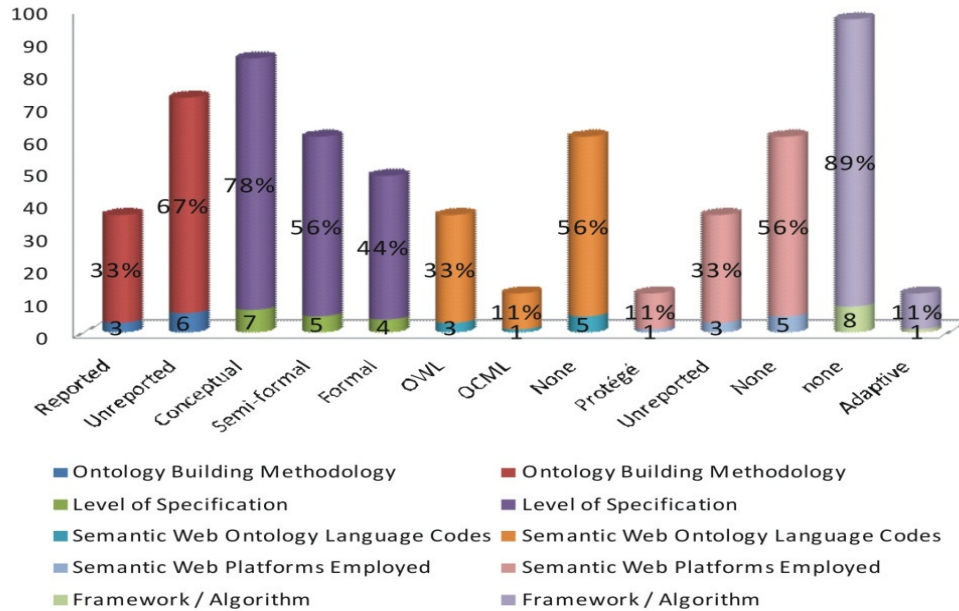


Figure 6: Chart of the comparison of this study with related research

4. CONCLUSION

This research has presented a detailed application of the Uschold and King [12] ontology building methodology for the development of semantic ontology models including conceptual/domain, semi-formal and formal ontologies in a government service domain. The research represents a practical case study application of an existing ontology building methodology for developing semantic ontology models in e-government. This may promote the use of existing ontology building methodologies in the Semantic Web development processes of government domain ontologies, facilitate the repeatability of the resulting domain ontologies in other e-government researches and projects, and strengthen the adoption of semantic technologies in e-government.

Although the study has focused on developing semantic ontology models for e-government applications, it also represents a contribution in the ontology engineering field in general and the Semantic Web domain in particular. In fact, the framework and techniques employed provides a practical application process of the Uschold and King [12] methodology which might be easily repeated in other domains of knowledge to build domain ontologies.

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CHAPTER V

Paper 4:

Combining Ontology Building Methodologies and Semantic Web Platforms for e-Government Domain Ontology Development

Combining Ontology Development Methodologies and Semantic Web Platforms for E-government Domain Ontology Development

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ABSTRACT

One of the key challenges in electronic government (e-government) is the development of systems that can be easily integrated and interoperated to provide seamless services delivery to citizens. In recent years, Semantic Web technologies based on ontology have emerged as promising solutions to the above engineering problems. However, current research practicing semantic development in e-government does not focus on the application of available methodologies and platforms for developing government domain ontologies. Furthermore, only a few of these researches provide detailed guidelines for developing semantic ontology models from a government service domain. This research presents a case study combining an ontology building methodology and two state-of-the-art Semantic Web platforms namely Protégé and Java Jena ontology API for semantic ontology development in e-government. Firstly, a framework adopted from the Uschold and King ontology building methodology is employed to build a domain ontology describing the semantic content of a government service domain. Thereafter, UML is used to semi-formally represent the domain ontology. Finally, Protégé and Jena API are employed to create the Web Ontology Language (OWL) and Resource Description Framework (RDF) representations of the domain ontology respectively to enable its computer processing. The study aims at: (1) providing e-government developers, particularly those from the developing world with detailed guidelines for practicing semantic content development in their e-government projects and (2), strengthening the adoption of semantic technologies in e-government. The study would also be of interest to novice Semantic Web developers who might used it as a starting point for further investigations.

KEYWORDS

E-government, Semantic Web, Ontology, Java Jena API, Protégé, RDF, OWL

1. INTRODUCTION

In the past ten years, e-government has been a subject of interest of governments around the world. Governments worldwide are expecting e-government to improve their internal processes and provide Internet and ICT-based service delivery to citizens, businesses and organizations. This requires the design, implementation and launch of web-based systems that present government structures and services online, provide mechanisms for online interaction of government with citizens, and facilitate online citizen participation to government processes and decision making. These mandates of e-government can only be achieved if a large range of government's services and processes are delivered seamlessly to citizens and stakeholders

through a single web portal [1], [2]. This raises the issue of developing heterogonous web-based e-government systems of government departments and agencies that can interoperate and be easily integrated. Although the state-of-the-art software engineering techniques including object-oriented and agile methods provide appropriate solutions to the aforementioned engineering problems of services integration and interoperability in e-government [1], [3], [4], it has been demonstrated that they have certain limitations [3], [4], [5], [6]. Therefore, during the past six years, Semantic Web technologies have emerged as promising solutions to these problems [3], [4], [7], [8], [16].

Semantic-based e-government consists of describing existing entities, concepts, processes, laws and regulations governing a government service domain, into a conceptual model namely domain ontology. This domain ontology is initially represented in a human readable form. Then, to make it processable by computers, ontology editing and implementing platforms should be used by e-government developers to develop the domain ontology in Semantic Web machine processable syntaxes such as XML, RDF, and OWL. In light of the above, practicing semantic development in e-government could be challenging to e-government system developers without any knowledge of ontology and Semantic Web technologies. Thus, there is a need for detailed research in the field of e-government that focuses on ontology development using available ontology development methodologies and open-source Semantic Web development platforms. To the best of our knowledge, current research focusing on semantic e-government development [3], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16] has not yet filled this gap. Furthermore, only a few of current works provide detailed guidelines for developing government domain ontology from a government service domain.

This research presents a case study combining an ontology building methodology and two state-of-the-art Semantic Web platforms, namely Protégé and Java Jena ontology API, for semantic ontology development in e-government. Firstly, a framework adopted from the Uschold and King [17] ontology building methodology is employed to build a domain ontology describing the semantic content of a government service domain. Thereafter, UML is used to semi-formally represent the domain ontology. Finally, Protégé and Jena API are employed to create the Web Ontology Language (OWL) and Resource Description Framework (RDF) representations of the domain ontology respectively to enable its computer processing. The study aims at: (1) providing e-government developers, particularly those from the developing world, where there is little or no use of Semantic Web technologies in e-government, with detailed guidelines for practicing semantic content development in their e-government projects and (2), strengthening the adoption of semantic technologies in e-government. The study would also be of interest to novice Semantic Web developers who might use it as a starting point for further investigations.

The rest of the paper is organized as follows. Section 2 presents existing languages for ontology representation in Semantic Web. The software platforms for ontology development are described in Section 3. Section 4 conducts a literature review on the state of usage of Semantic Web technologies in e-government to date. The existing methodologies for building ontologies as well as the stages of ontology development are discussed in Section 5. Section 6 presents a case study development of a government domain ontology combining ontology development methodology and Semantic web platforms, including Protégé and Jena API. A discussion is carried out in Section 7 and a conclusion is drawn in the last section.

2. ONTOLOGY LANGUAGES FOR THE SEMANTIC WEB

The Semantic Web [18] is an evolution of the current Web that provides meanings to Web contents to enable their intelligent processing by computers. The meanings of Web contents are

represented with ontology and described formally in logic-based syntaxes to facilitate their integration and accessibility over the Web [19]. The logic-based description of ontology is carried out with Semantic Web ontology languages such as XML, XML Schema (XMLS), RDF, RDF Schema (RDFS), and OWL. The work presented in this paper uses RDF(S) and OWL which are the leading Semantic Web ontology languages [6], [19], [20], [21].

2.1 RDF(S)

RDF and RDFS are the first standardized Web Based languages [19], [20]. RDF is a data model used to describe resources on the Web, whereas, RDFS is an improved version of RDF which provides facilities for the definition of basic ontology elements such as classes and hierarchy of classes, properties, domain and range of properties [19], [20]. RDF uses statements in the form of $\langle S, P, O \rangle$ to represent an ontology. The meaning of a RDF statement is that subject S has property P with value O. In a RDF statement, S and P are uniform resource identifiers (URIs), while O is either a URI or a literal value [6].

2.2 OWL

OWL was developed to overcome the weak expressive power of RDF(S) [19], [20], [21]. The expressivity of RDF(S) is enhanced by OWL with tools for: describing relations between classes, defining properties' characteristics, cardinality and value restrictions on properties, etc. [19], [20].

In practice, Semantic Web developers do not have to write RDF(S) and/or OWL codes by hand; several software platforms exist for the automatic development of RDF(S) and OWL codes. The next section expands more on existing software platforms for Semantic Web ontology development.

3. SOFTWARE PLATFORMS FOR SEMANTIC WEB ONTOLOGY DEVELOPMENT

To support the vision of the Semantic Web which is making machine-readable content available on the Web, several software platforms and application interfaces (APIs) have been developed to permit the automatic creation and use of RDF(S) and OWL ontologies. Recent comparative studies of some of the existing RDF(S) and OWL editing platforms are provided in [21], [22]. A more exhaustive list of these platforms could be found in [21], [22], [23], [27]; they include Protégé, WebODE, OntoEdit, KAON1, and so forth. Beside the software platforms used for the edition of RDF(S) and OWL ontologies, there exist APIs such as OWL API [23], Jena API [6], Sesame [5], etc., which provide facilities for the persistence storage and query of RDF(S) and OWL ontologies. Protégé and Jena API are discussed and used in this study as they are the leading platforms for Semantic Web development [6], [21], [22]; furthermore, they are both open-source software and might facilitate the repeatability of this study.

3.1 Protégé

Protégé is an open-source platform developed at Stanford Medical Informatics. It provides an internal structure called model [23] for ontologies representation and an interface for the display and manipulation of the underlying model. The Protégé model is used to represent ontology elements as classes, properties or slots, property characteristics such as facets and constraints, and instances. The Protégé graphical user interface can be used to create classes and instances, and set

class properties and restrictions on property facets. Additionally, Protégé has a library of various tabs for the access, graphical visualization, and query of ontologies. Protégé can be currently used to load, edit and save ontologies in different formats including XML, RDF, UML, and OWL [23].

3.2 Jena API

Jena is a Java ontology API. It provides object classes for creating and manipulating RDF graphs called interfaces. A RDF graph is called a model and represented with the Model interface. The resources, properties and literals describing RDF statements are represented with the Resource, Property and Literal interfaces respectively. Jena also provides methods that allow saving and retrieving RDF graphs to and from files. The Jena platform supports various database management systems such as PostgreSQL, MySQL, Oracle, and so on; it also provides various tools including RDQL query language, a parser for RDF/XML, I/O modules for RDF/XML output, etc. [6]. The state of use of Semantic Web technologies in e-government is presented in the next section.

4. BACKGROUND ON THE USE OF SEMANTIC WEB TECHNOLOGIES IN E-GOVERNMENT

In the past six years, e-government has been one of the most active areas of Semantic Web development. However, current research practicing semantic development in e-government does not focus on the application of available methodologies and platforms for developing government domain ontologies. In [9], a process-document ontology describing the document hierarchy and the structure of the business processes in e-government is modelled using RDF and OWL graphical representations. However, no practical implementation was discussed to illustrate how the proposed process-document ontology can be created with existing Semantic Web editing and representation platforms.

Xiao et al. [8] and Sabucedo et al. [16] proposed specific e-government domain ontologies to address the issue of service integration in e-government; the proposed ontology models were represented in OWL for semantic processing. However, no information was given on the platforms employed to generate the OWL versions of the proposed ontology models.

Other semantic-based solutions for e-government services integration and interoperability based on specific ontology models are proposed in [7], [10]. The proposed ontology models were developed in OWL using dedicated platforms namely ONTOGOV [7] and IESD [10], respectively. However, the platforms employed are proprietary and little information is provided for their widespread use within the e-government community.

The analysis of other relevant literature by Sabucedo and Rifon [11], Chen et al. [12] and Gugliotta et al. [13] reveals other specific ontology models describing various aspects of e-government service delivery. However, the proposed ontology models were only presented at the conceptual level. Further, none of the works has provided clues on how the proposed ontology models can be constructed from the complex public administration system with existing ontology building methodologies.

The issue of services interoperability in e-government is further addressed in Muthaiyah and Kerschberg [3], Zhang and Wang [14] and Bettahar et al. [15] with ontology-based solutions; the ontology components of the proposed solutions are modeled in OWL [3], [14], [15] and Semantic Web Rule Language (SWRL) [3], [14] with Protégé to enable the semantic interoperability of e-

government services. Although these studies have used Protégé for semantic ontology development, they did not focus on the methodological approach for semantic ontology development in e-government; then, it is not clear how the ontology components of the proposed interoperability solutions were built from the complex public administration system until their implementation with Protégé.

In summary, the above research demonstrate the interest in Semantic Web technologies based on ontology in e-government; they show how various ontology models are being used in e-government researches and projects to describe and specify e-government services, aiming at their semantic integration and interoperability. However, the ontology models employed were only presented at the conceptual level [9], [11], [12], [13]; in certain cases, no details of the implementation platforms were given [8], [16]; and some of them were developed with proprietary platforms [7], [10]. Further, none of the current research provides guidelines for constructing the proposed semantic ontology models from the complex public administration system using existing ontology building methodology provided in the ontology engineering field. All these factors do not facilitate the repeatability of various ontology-based solutions for e-government services integration and interoperability that are being proposed in various e-government researches and projects nor do they contribute to the widespread adoption of Semantic Web technologies in e-government. The next section explains the ontology development process.

5. ONTOLOGY DEVELOPMENT PROCESS

5.1 Ontology Development Methodologies

At present, there is no universal definition of ontology in the literature. Ontology is commonly defined as an explicit specification of a conceptualization [24] i.e., a model of the real world domain such as medicine, geographic information system, physics, e-government and so forth; which is explicitly represented with existing objects, concepts, entities and relationships between them. The above definition of ontology shows that developing an ontology for a given domain of knowledge could be a complex and challenging task [23]; especially for a complex domain such as the public administration system. Therefore, ontology developers need appropriate methodologies that will guide them in the process of building an ontology characterizing a particular domain.

To this end, a considerable amount of research has been done in the field of ontology engineering to develop proper methodologies for ontology development. Detailed comparative studies of these methodologies are provided in [25], [26], [27]. The ontology development methodologies prescribe various steps and tasks that must be performed when building ontology. To the best of our knowledge, none of the current research practicing semantic ontology development in e-government has referred to a particular methodology that was employed when building the proposed e-government specific ontology models. This may not ease the repeatability of the proposed ontology-based solutions by e-government developers without any knowledge of ontology and Semantic Web technologies.

The primary objective of this study is to provide e-government developers, particularly those from the developing world, with guidelines for practicing Semantic content development in their e-government projects. Therefore this research presents a case study of semantic ontology development in e-government. A framework adopted from the Uschold and Kind [17] ontology building methodology is applied to build a domain ontology from a government service domain.

The domain ontology is further developed in RDF and OWL with Protégé and Java Jena ontology API to enable its semantic processing by computers.

5.2 Phases of Ontology Development

A rigorous development process for ontology building requires the use of its development methodologies and platforms. A methodology mainly prescribes guidelines for the specification, conceptualization, formalization and implementation of ontology [27]. The specification phase defines the aims and roles of the intended ontology as well as people who will be using it. During the conceptualization phase, a conceptual or domain ontology is built. In its simple representation, a conceptual or domain ontology is a graph where the vertices are objects, concepts, and entities of the domain, and the edges are lines interconnecting pairs of vertices and representing the relationships between the constituents of the domain. The formalization phase transforms the conceptual model or domain ontology into its semi-formal representation; this can be done either in description logic [29] or UML formalisms [30]. The UML formalism is used in this study because it is widely used by software developers for object-oriented systems development. During the implementation phase of ontology development, the semi-formal version of the ontology is formally represented in one of Semantic Web languages with ontology editing platforms (see sections 2 and 3).

After its formal representation, the developed ontology has to be effectively used by its intended users. Therefore, the formal ontology must be deployed onto the Web using programming platforms such as Java, C++, .NET, etc. This provides facilities for database storage and querying of the developed ontology.

To fulfil the objectives of this study, which are to provide e-government developers with detailed guidelines for practicing semantic content development in their e-government projects and strengthen the adoption of semantic technologies in e-government, the main phases of ontology development presented above are applied to develop a government domain ontology using a framework adopted from the Uschold and King [17], [28] methodology and Protégé and Java Jena ontology API platforms.

The Uschold and Kind [17] methodology was chosen in this study for its clarity and the fact that it is technology and platform independent [25]; which might facilitate its use by novice ontology developers and promote a fast development of domain ontologies.

6. APPLICATION

This section presents a case study development of government domain ontology.

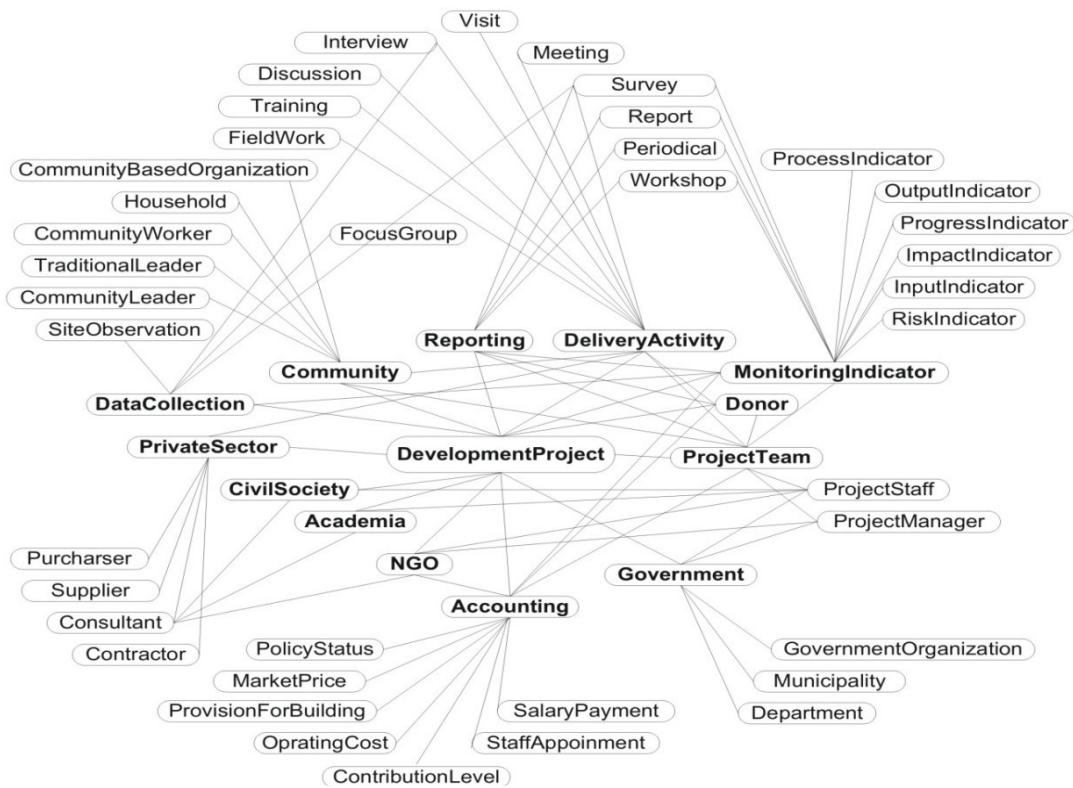


Figure 1: OntoDPM Domain Ontology

6.1 Presentation of the Government Service Domain

The government service domain used in this study is the domain of development projects monitoring in developing countries. In fact, in developing countries as well as in Sub Saharan Africa (SSA), almost every government department is somehow involved in the implementation of a programme aiming at improving the welfare of its people. These programmes are commonly called development projects and include infrastructure development, water supply and sanitation, education, rural development, health care, ICT infrastructure development and so forth. Thus, application that could interface all the activities related to development projects implementation in a SSA country could bring tremendous advantages. For example, such a web application would improve the monitoring and evaluation of projects and provide transparency, efficiency and better delivery to populations. In a previous study [28], we built a domain ontology of development projects monitoring (OntoDPM) for such an application. The next subsections describe the methodology and platforms employed.

6.2 OWL Representation of the OntoDPM Domain Ontology

A framework adopted from the Uschold and King [17] ontology building methodology was used in [28] to build the OntoDPM as in Figure 1. The OntoDPM shows the key concepts of the domain (people, stakeholder, financier, monitoring indicator, reporting technique, etc.), the activities carried out in the domain (training, discussion, fieldwork, visit, meeting, etc.) and the

relationships between the constituents of the domain. This study does not expand on the framework for building the OntoDPM in Figure 1. Interested readers may refer to [28] for detailed information. The OntoDPM in Figure 1 was further written semi-formally in UML and implemented in OWL using Protégé [31], [32].

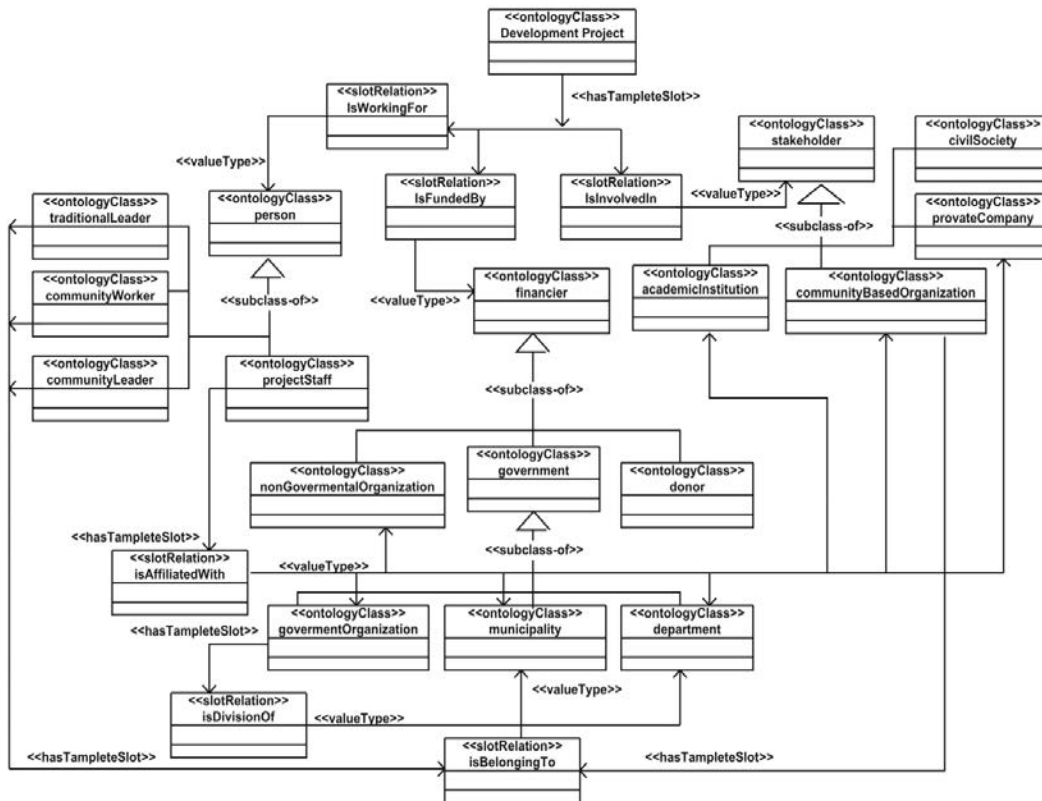


Figure 2: Part of UML Class Diagram of the OntoDPM Domain Ontology

The UML representation of the OntoDPM was constructed by identifying classes and class instances in the OntoDPM in Figure 1 and categorizing relationships between classes (composition, association, inheritance). Figure 2 represents a part of classes, inheritance structure and properties/slots of the OntoDPM, in the UML formalism for knowledge representation [30]. This formalism was chosen because it allows modeling ontologies with instances/individuals, slots and classes, which are the terminologies of Protégé as well [31]. In this formalism, a class is labelled "ontology class", a property/slot "slot relation" and an instance/individual "IndividualOf". Properties/slots represent the relationships between the concepts of the domain ontology. Each slot has a domain and a range which are labelled *hasTemplateSlot* and *valueType*, respectively. The inheritance relationship between classes is labelled "subclass-of".

The OWL version of the OntoDPM was created with Protégé (see part in Table 1) using its semi-formal representation (see part in Figure 2). Firstly, we downloaded Protégé version 4.0 from the Stanford Medical Informatics website and installed it in our computer; related documentations [31], [32] were downloaded as well. Thereafter, the user-friendly graphical user interface of Protégé was used to create the class hierarchy (classes, instances and inheritance structure), slots, and domain and range of slots respectively. These features of the OntoDPM were created based

on its UML representation (see part in Figure 2). The resulting Protégé file was saved as an OWL file onto the disc.

Table 1: Part of OWL Version of the OntoDPM Domain Ontology

```

---
<owl:Class rdf:about="#Stakeholder">
<owl:Class rdf:about="#CivilSociety">
<rdfs:subClassOf rdf:resource="#Stakeholder"/>
</owl:Class>
<owl:Class rdf:about="#PrivateCompany">
<rdfs:subClassOf rdf:resource="#Stakeholder"/>
</owl:Class>
<owl:Class rdf:about="#AcademicInstitution">
<rdfs:subClassOf rdf:resource="#Stakeholder"/>
</owl:Class>
<owl:Class rdf:about="#CommunityBasedOrganization">
<rdfs:subClassOf rdf:resource="#Stakeholder"/>
</owl:Class>
<owl:Class rdf:about="#Financier">
<owl:Class rdf:about="#Donor">
<rdfs:subClassOf rdf:resource="#Financier"/>
</owl:Class>
<owl:Class rdf:about="#Government">
<rdfs:subClassOf rdf:resource="#Financier"/>
</owl:Class>
<owl:Class rdf:about="#NonGovernmentalOrganization">
<rdfs:subClassOf rdf:resource="#Financier"/>
</owl:Class>
---
<owl:ObjectProperty rdf:about="#IsFunderBy">
<rdfs:domain rdf:resource="#DevelopmentProject"/>
<rdfs:range rdf:resource="#Financier"/>
</owl:ObjectProperty>
<owl:ObjectProperty rdf:about="#IsInvolvedIn">
<rdfs:domain rdf:resource="#DevelopmentProject"/>
<rdfs:range rdf:resource="#Stakeholder"/>
</owl:ObjectProperty>
---

```

The code in Table 1 was obtained by opening the saved OWL file with open-source programming editors such as JCreator and JGrasp. Table 1 presents parts of the *subclass-of* relationships (inheritance) and domains and ranges of slots in the OntoDPM. It is worth noting that the concepts of class, property/slot, domain and range, and individual/instance used in the UML representation of the OntoDPM (see part in Figure 2), are concepts of Protégé as well; this indicates that the formalism employed in Figure 2 is appropriate for representing a semi-formal ontology to be implemented with Protégé. A complete description of OWL syntax is beyond the

scope of this research; the study aims to provide guidelines for creating OWL ontology with Protégé, based a semi-formal UML representation of domain ontology such as the OntoDPM. Further information on the OWL syntax and its development with Protégé could be found in [31] and [32]. In the following subsection, Java Jena ontology API is employed to create the RDF formal representation of the OntoDPM.

6.3 RDF Representation of the OntoDPM Domain Ontology

Let's recall that RDF is a Semantic Web language for representing resources on the Web. A resource is any information that can be accessed over the Web using an URI. Three concepts are fundamental in RDF including subject (S), predicate (P) and Object (O). A subject is a resource to be referred to on the Web; a predicate is a property describing the resource and an object is a value of the property. Thus, the triplet <S, P, O> describes the same information and forms an RDF graph or statement [6]. An RDF graph or statement is graphically represented with two nodes and one arc; where, the arc is the property that describes the resource and the nodes at both sides of the arc, the resource and property's value respectively. In light of the above, the RDF syntax represents each class of an ontology as a resource which has properties with values. Thus, an ontology will be represented in RDF with several statements where each statement or a set of related statements forms an RDF sub-graph of the entire RDF graph of the intended ontology.

```

Java - JenatTutorial/src/OntoDPM_Jena_Development/DevelopmentProjectClassStructure.java - Eclipse SDK
File Edit Source Refactor Navigate Search Project Run Window Help

public static Model unionRDFfile(String fileName) {
public static void displayOntoDPMStatements(Model m) {
public static void main(String[] args) {
    // declare URIs
    String devprojURI = "http://OntoDPM/DevelopmentProject";
    String personURI = "http://OntoDPM/Person";
    String financierURI = "http://OntoDPM/Financier";
    String sthdURI = "http://OntoDPM/Stakeholder";
    String monIndjURI = "http://OntoDPM/MonitoringIndicator";

    Model devProjGraph = ModelFactory.createDefaultModel();

    //declare resources
    Resource devproj = devProjGraph.createResource(devprojURI);
    Resource person = devProjGraph.createResource(personURI);
    Resource financier = devProjGraph.createResource(financierURI);
    Resource sthd = devProjGraph.createResource(sthdURI);
    Resource monInd = devProjGraph.createResource(monIndjURI);

    //set RDF structure
    devproj.addProperty(RDF.predicate, person);
    devproj.addProperty(RDF.predicate, financier);
    devproj.addProperty(RDF.predicate, sthd);
    devproj.addProperty(RDF.predicate, monInd);

    Model model2 = unionRDFfile("OntoDPM_FinancierClassHierarchy.txt");
    Model model3 = unionRDFfile("OntoDPM_PersonClassHierarchy.txt");
    Model model4 = unionRDFfile("OntoDPM_MonitoringIndicatorInstances.t
    Model model15 = unionRDFfile("OntoDPM_StakeholderClassHierarchy.txt"
    //Model m = unionRDFfile("c:\\Protege\\OntoDPM.owl");

    Model rdf = devProjGraph.union(model2)
        .union(model3)
        .union(model4)

```

Figure 3: Screenshot of the Jena Implementation of the OntoDPM Domain Ontology

The RDF version of the OntoDPM was created with the Java Jena Ontology API. Firstly, we downloaded, installed and configured the Jena API in the Eclipse Java software development kit (SDK). As there are many classes in the OntoDPM, it was difficult to handle the same Jena RDF model to create all of them. We found that the Jena Model interface provides the union method that can be used to integrate different branches of a large RDF graph. Then, we created the main components (inheritance and instances) of the OntoDPM as individual Java files (see the left part of Figure 3). In each of the Java files, the main() method was included to generate and write the corresponding RDF sub-graph into a text file. Thereafter, we coded a method to read each text file and construct its RDF sub-graphs with the Jena Model interface. Finally, the individual RDF sub-graphs were integrated with the union method of the Model interface, in a unique RDF graph of the OntoDPM.

Table 2: Part of RDF Representation of the OntoDPM Domain Ontology

```

<rdf:RDF
  xmlns:rdf=http://www.w3.org/1999/02/22-rdf-syntax-ns#
  <rdf:Description rdf:about="http://OntoDPM/DevelopmentProject">
  <rdf:predicate>
  <rdf:Description rdf:about="http://OntoDPM/Stakeholder">
  <rdf:predicate rdf:resource="http://OntoDPM/CivilSociety"/>
  <rdf:predicate>
  <rdf:Description rdf:about="http://OntoDPM/PrivateCompany">
  <rdf:object rdf:resource="http://OntoDPM/Consultant"/>
  <rdf:object rdf:resource="http://OntoDPM/Purchaser"/>
  <rdf:object rdf:resource="http://OntoDPM/Contractor"/>
  <rdf:object rdf:resource="http://OntoDPM/Supplier"/>
  </rdf:Description>
  </rdf:predicate>
  <rdf:predicate rdf:resource="http://OntoDPM/AcademicInstitution"/>
  <rdf:predicate rdf:resource="http://OntoDPM/CommunityBasedOrganization"/>
  </rdf:Description>
  </rdf:predicate>
  <rdf:Description rdf:about="http://OntoDPM/Financier">
  <rdf:predicate rdf:resource="http://OntoDPM/NonGovernmentalOrganization"/>
  <rdf:predicate>
  <rdf:Description rdf:about="http://OntoDPM/Government">
  <rdf:predicate rdf:resource="http://OntoDPM/Agency"/>
  <rdf:predicate rdf:resource="http://OntoDPM/Municipality"/>
  <rdf:predicate rdf:resource="http://OntoDPM/Department"/>
  <rdf:object>Institute of Nuclear Research</rdf:object>
  <rdf:object>Department of Health</rdf:object>
  <rdf:object>Ekhurhuleni</rdf:object>
  </rdf:Description>
  </rdf:predicate>
  <rdf:predicate rdf:resource="http://OntoDPM/Donor"/>
  </rdf:Description>
  </rdf:predicate>
  ---

```

```
</rdf:Description>
</rdf:RDF>
```

A part of the code for integrating the RDF sub-graphs is depicted on the right side of Figure 3. Table 2 shows a part of the generated RDF code of the OntoDPM. One can notice that RDF code is not as readable as an OWL code because of the weak expressive power of RDF mentioned earlier in this study. However, Table 2 illustrates the representation of a part of the OntoDPM class hierarchy and instances with basic RDF concepts of resource, predicate and object. A complete explanation of the development of RDF ontology with Jena API is beyond the scope of this research. Further information on how to use Jena API to develop ontology in RDF syntax could be found in [33], [34]. A discussion and future direction of our research are presented in the next section.

7. DISCUSSION

The study has discussed Semantic Web ontology languages and software platforms for ontology development. A domain ontology was built with a framework adopted from the Uschold and King [17] ontology building methodology [28]. A semi-formal representation of the domain ontology was done with the UML formalism. Further, two state-of-the-art Semantic Web platforms for ontology development including Protégé and Java Jena API were used to generate the machine processable version of the domain ontology in OWL and RDF, respectively. It is worth highlighting that Jena API provides some useful features for ontology deployment. In fact, the Jena API provides the RDQL language for RDF storage and query with various database management systems including PostgreSQL, MySQL, Oracle [6], etc. However, the database storage and query of RDF ontology is out of the scope of this research and will be the focus of our future work. Furthermore, Jena API provides parsing mechanisms that could be exploited to read OWL ontology developed with Protégé and generate an RDF graph; this might facilitate the development of real-world Semantic Web applications where ontology edition is done with Protégé, while queries are handled with Jena interfaces. The parsing mechanism for bridging Protégé and Jena API will be investigated in our future work as well.

8. CONCLUSION

The study reviews the literature and points out that current research focusing on Semantic Web development in e-government does not refer to any existing ontology development methodology when reporting on either the e-government specific ontology models that they have developed or an ontology-based solution for e-government services integration and interoperability that they propose. The study has also pointed out that current research does not provide detailed guidelines for developing government domain ontology using available open-source Semantic Web platforms. All these factors do not ease the repeatability of the various specific ontology models being developed in e-government domain nor do they strengthen the adoption of semantic technologies in e-government.

As a solution, the study has developed a government domain ontology using a framework adopted from the Uschold and King ontology building methodology and two leading Semantic Web development platforms namely Protégé and Java Jena Ontology API. The framework used for ontology building provides clearly defined steps and their application and it is platform independent as well [28]. This may facilitate its use by novice ontology developers and promote a fast development of domain ontology. Furthermore the Semantic Web platforms employed

including Protégé and Java Jena Ontology API are all open-source software which are downloadable from the Internet. This may facilitate the repeatability of the study within the e-government development community and strengthen the adoption of semantic technologies in e-government.

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CHAPTER VI

Paper 5:

A Framework for Semantic Model Ontologies Generation for e- Government Applications

A Framework for Semantic Model Ontologies Generation for E-government Applications

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Abstract—The Web Ontology Language (OWL) standard is increasingly being used to build e-government service ontologies that are integrable and interoperable in e-government environments. However, current works employing OWL ontologies in e-government are more directed to the Semantic Web audience than to the broader e-government community. Furthermore, only a few of these works provide detailed guidelines for constructing OWL ontologies from a business domain. This paper presents a framework for generating semantic model ontologies in OWL syntax from a government service domain. Firstly, the government service domain is analyzed and a domain ontology is constructed to capture its semantic content. Thereafter, a semi-formal representation of the domain ontology is created with the ontology knowledge-base editor Protégé. Finally, the OWL ontology model is imported. This study aims at providing e-government developers, particularly those from the developing world, with an easy to use framework for practicing semantic knowledge representation in e-government processes; thus facilitating the design of e-government systems that can be easily integrated and maintained.

Keywords - E-government; Interoperability; Ontology; OWL; Protégé; Software Engineering.

I. INTRODUCTION

In recent years, many countries worldwide have adopted e-governance, resulting in several applications being developed in various government departments and agencies. The increasing number of autonomous e-government applications has raised several software engineering issues as reusability, maintenance, integration, and interoperability of these applications [1][2][3][4], in the context of one-stop e-government which requires e-government applications to be accessed at a single point and function as a whole for better efficiency [1][5]. In an attempt to address the above issues, semantic model ontologies using the OWL Web Service Standard are frequently used. OWL ontologies allow the composition [7][8], searching, matching, mapping and merging [9][10] of e-services and facilitate their integration [5][8][9], maintenance [8][9] and interoperability [3][7][10][11].

Many works describe ontology modelling and implementation activities in e-government [6][3][7][10][11].

These works demonstrate that OWL is a common language employed for semantic knowledge representation in e-government. However, in this research, we argue that the above works are more directed to the Semantic Web audience than to the broader e-government community. Furthermore, only a few of these works provide detailed guidelines for constructing OWL ontologies from an e-government service domain. This paper presents a framework for generating semantic model ontologies in OWL syntax, from a government service domain. Firstly, the government service domain is analyzed and its domain ontology is constructed. Thereafter, a semi-formal representation of the domain ontology is created and implemented with the ontology knowledge base editor Protégé. Finally, the OWL ontology model is imported. The study aims at providing e-government developers, particularly those from the developing world, with an easy to use framework for practicing semantic knowledge representation in e-government processes; which allow building e-government systems that can be easily integrated and maintained.

The rest of the paper is organized as follows. Section 2 defines ontology and gives its roles in the software engineering field. Ontology modelling and implementation activities in e-government are reviewed in Section 3. The languages and software tools for representing and editing ontologies are presented in Section 4. Section 5 presents the framework for OWL ontology generation. A case study application of the framework is conducted in Section 6. Section 7 carries out a discussion and a conclusion is drawn in the last section.

II. DEFINITION AND ROLES OF ONTOLOGY

There are several definitions of ontology in the literature [12]; the most commonly used definition is taken from Gruber [13]. He defined an ontology as an explicit specification of a conceptualization. A conceptualization refers to an abstract and simplified view of a domain of knowledge one wishes to represent for a certain purpose. The domain could be explicitly and formally represented using existing objects, concepts, entities and the relationships that exist between them [13]. The

domain could refer to a domain such as medicine, geographic information system, or e-government; it could also refer to an area of problem solving or a knowledge representation language [14]. Ontologies are widely used in disciplines such as software engineering, databases, artificial intelligence, and many more [15]. In these fields, developers use ontologies to represent knowledge in a manner that can be automatically processed by a machine. In [16] and [17] the authors argued that because an ontology represents the concepts of a domain of knowledge and the relationships between them, it provides a shared and common understanding of the structure of information among people and software agents. It also facilitates software development and improves processes in the corresponding domain. Aside from the semantic representation of concepts of a domain of knowledge, an ontology also provides a data type description which specifies the data component of applications [19]. Ontologies are application independent, which allow domain knowledge reuse and easy software maintenance, and contribute to the semantic interoperability of applications [13]. Due to the complexity of government processes various government departments need ontologies to streamline, re-organize government services and to facilitate the integration, maintenance and interoperability of their e-government systems [19][20]. Some works illustrating the current practice of using ontologies in e-government systems are provided in the next section.

III. USE OF ONTOLOGY IN E-GOVERNMENT

Salhofer et al. [6] presented an ontological approach for service integration in e-government. A semantic objective and service discovery technique was used to illustrate how e-services could be derived from citizens' needs expressed in the form of simple phrases. The derived e-service ontologies were represented in OWL and the Web Service Modelling Language (WSML). Another ontological approach for semantic interoperability in e-government was proposed by Muthaiyah and Kershberg in [3]. They used a shared hierarchical ontology in which knowledge is organized at different levels with local ontologies. A semantic bridging process methodology was described for the mapping, merging and integration of local ontologies represented in an OWL syntax. In [7], an intelligent platform to host e-government services in the form of a customer-oriented e-government Web portal was put forward. To facilitate services and related public administrations interoperability they introduced the concept of an intelligent document and a Life Event service both of which are semantically modelled with OWL ontology. These allow automatic services composition, advanced searching mechanisms and better usability from the user's point of view. In [8] and [9] the authors presented a software engineering platform for the development and management of e-government services namely ONTOGOV. The ONTOGOV platform uses Semantic Web technologies including OWL-S and Web Service Modelling Ontology (WSMO) to construct eight types of ontologies characterizing the e-government domain; they include: legal ontology, organizational ontology, life-cycle ontology,

domain ontology, service ontology, life-event ontology, profile ontology, web service orchestration ontology. These ontologies aim at describing and composing services provided by public administrators. In particular, the life-cycle ontology is used to carry out the maintenance of e-services and the web service orchestration ontology is used for software components and service ontology integration [9]. A multilevel abstraction of life-events for e-government services integration was presented in [10]. In their work, a life-event is defined as a collection of actions needed to deliver a public service satisfying the needs of a citizen in a real-life situation and is modelled using three kinds of ontologies: e-government ontology, regulatory ontology and service ontology. The ontologies are represented in OWL to enable dynamic services integration through semantic searching and matching of concepts [10]. Xiao et al. [11] present yet another ontology-based approach for semantic interoperability in e-government. They describe the business process of e-government services using an E-government Business Ontology (EG-BOnt). Each business process is described in terms of its input, output, resource constraints and logical relations with other relevant businesses. Thereafter, each class of the EG-BOnt is defined using the OWL language for its strong semantic and logic relation expressiveness [11]. Finally, an architecture describing a semantic interoperability framework between different government systems based on the proposed EG-BOnt was presented.

IV. ONTOLOGY REPRESENTATION LANGUAGES

The Semantic Web domain provides various languages for representing ontologies including XML, RDF, DAML, and OWL [21]. OWL is the most widely used of these languages because of its high expressive power and the fact that it is the W3C standard ontology language for the Semantic Web [24][26]. Several software tools are used for ontology edition including WebODE, OntoEdit, KAONI, and Protégé [18]. Ontology developers prefer Protégé for its ease of use and its abstraction capabilities; it has a graphical user interface which enables ontology developers to concentrate on conceptual modelling without any knowledge of the syntax of the output language [24]. Furthermore, Protégé is open-source software which is downloadable from the Stanford Medical Informatics website. This paper gives a step-by-step guideline on how e-government developers can design and generate OWL ontologies using Protégé. The next section presents the proposed framework for constructing OWL ontologies from an e-government service domain using Protégé.

V. FRAMEWORK FOR OWL ONTOLOGIES GENERATION

The framework starts with an e-government service domain as an input. Domain experts and different information sources are consulted to describe the business process of the domain. A domain ontology is then built to capture the relevant concepts, activities, tasks, regulations and relationships between all the constituents of the e-government service domain. Thereafter, a semi-formal representation of the domain ontology is constructed in the form of a class diagram in UML syntax; this

TABLE I
DESIGN DETAILS OF THE ONTODPM CLASS DIAGRAM

Classes	
Development project, monitoring indicator, delivery activity, reporting technique, person, stakeholder, financier, community leader, traditional leader, community worker, project staff, consultant, academic institution, community based organization, civil society, private company, government, donor, non-governmental organization, agency , municipality, department, accounting activity, data collection technique	
Inheritance Structure	
Super Class	Sub Classes
Person	project staff, community leader, community worker, traditional leader
Financier	government, donor, non-governmental organization
Stakeholder	academic institution, civil society, private company, community based organization
Government	department, municipality, agency
Class Instances	
Class	Instances/Individuals
Monitoring indicator	input indicator, output indicator, impact indicator, risk indicator, process indicator, progress indicator
Delivery activity	survey, meeting, visit, discussion, training, fieldwork, interview
Reporting technique	workshop, written report, periodical, survey
Accounting activity	operating cost, salary payment, contribution level, provision for building, policy status, staff appointment, market price
Data collection technique	site observation, focus group, interview, survey

(composition, association, inheritance). Further, we followed the UML syntax for knowledge representation [16] to represent the semi-formal version of the OntoDPM in UML as depicted in Figure 3. We have chosen the UML knowledge representation formalism because it allows modelling ontologies with instances/individuals, slots and classes, which are also used in Protégé [23].

D. Develop Ontology

We have used the ontology knowledge base editor Protégé [23] to implement the UML class diagram of the OntoDPM in Figure 3. We saved the Protégé file as an OWL file onto the disc; Figure 4 depicts the location and the OWL file icon onto the disc. The Protégé version of the OntoDPM with some hidden components is shown in Figure 5. From the saved OWL file, the OWL ontology will be imported using an appropriate editor.

E. Export the OWL Ontology

Many editors were tested to import/open the OWL file; we found that programming editors including Microsoft Visual Studio, JCreator, and JGrasp could import the OWL file successfully. Figure 6 and Figure 7 show the imported OWL ontology in JCreator and Microsoft Visual Studio respectively.

VII. DISCUSSION

A detailed discussion on the use of the generated OWL ontology is out of the scope of this paper and will be the focus of our future work. Nevertheless, generating an OWL ontology from a e-government business domain as demonstrated in this

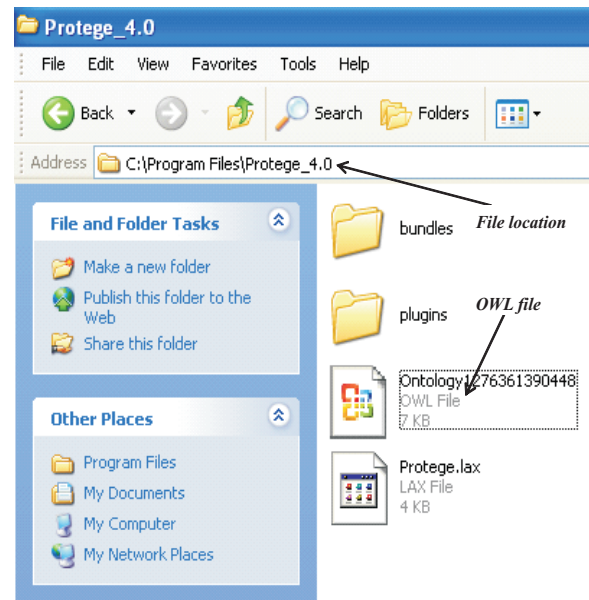


Fig. 4. OWL File and Location onto the Disc

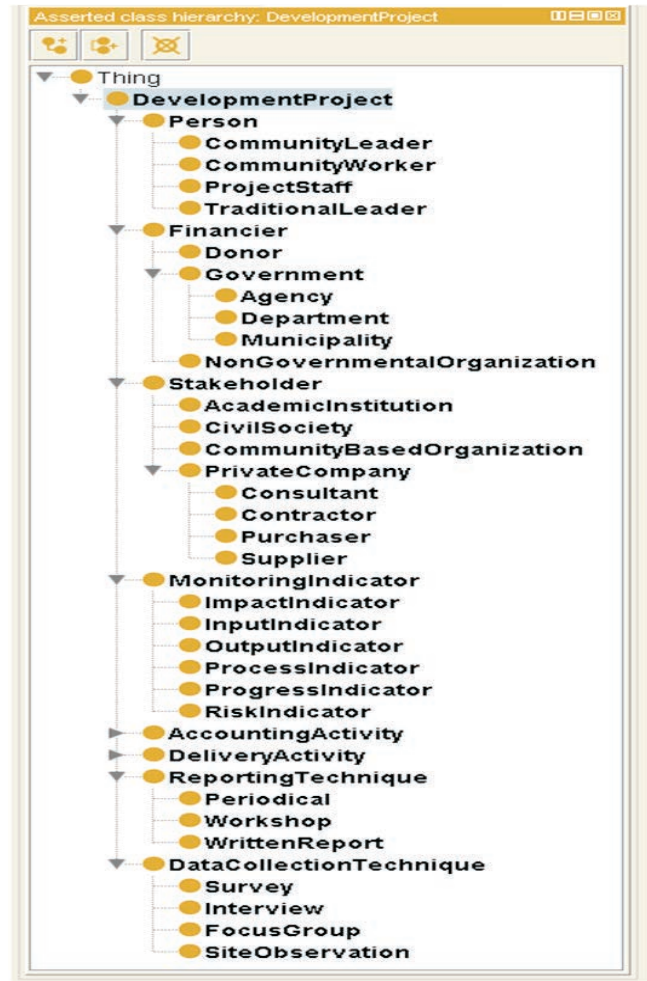


Fig. 5. Protégé Version of the OntoDPM



Fig. 6. OWL Ontology Imported with JCreator



Fig. 7. OWL Ontology Imported with Microsoft Visual Studio

paper is an important step towards the development of Semantic Web applications as e-government applications, which have potential to perform semantic inference and reasoning over the OWL ontologies and facilitate software components integration and interoperability. Moreover, many platforms as Java API, .NET, ASP and so forth, exist for developing Semantic Web applications based on OWL ontologies [4][25].

VIII. CONCLUSION

This study has presented a framework for constructing semantic model ontologies in OWL Web Service Standard for e-government applications. The proposed framework uses

simple ontology engineering techniques (modelling and representation techniques) to capture the semantic content of an e-government service business domain; this makes the framework easy to understand and user-friendly. Furthermore, the platform employed includes Protégé, JCreator, and JGrasp, to create and import the OWL ontology. These are mainly open source software; which make the framework usable by the broader e-government community, particularly e-government developers from the developing countries where there is little or no practice of semantic content representation for e-government systems.

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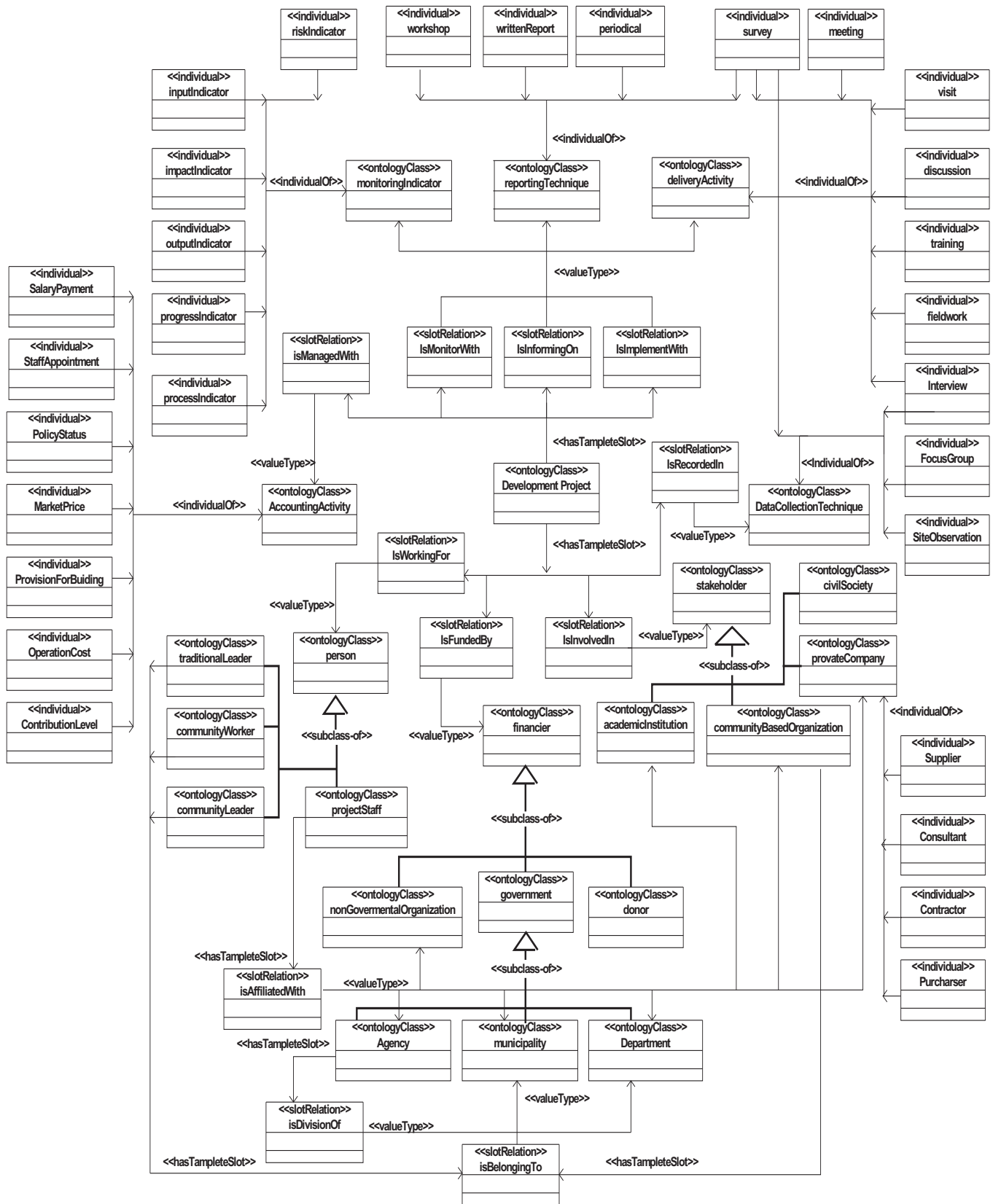


Fig. 3. Semi-formal UML Representation of the OntoDPM

CHAPTER VII

Paper 6:

Semantic-Driven e-Government: Correlating Development Phases with Semantic e-Government Specific Ontology Models

Semantic-Driven eGovernment: Correlating Development Phases With Semantic eGovernment Specific Ontology Models

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Abstract: Electronic government (eGovernment) has been one of the most active areas of ontology development during the past six years, resulting in several eGovernment Specific Ontology Models (ESOM) being developed in various researches and projects. However, the specific ontology models proposed are not aligned to any circumstance or phase of eGovernment development nor are detailed guidelines provided to facilitate their repeatability in the broader eGovernment community. This paper establishes a correlation between existing ESOM and eGovernment development phases. Firstly, ESOM developed in various eGovernment researches and projects are investigated and encoded. Thereafter, a semantic-driven eGovernment development framework based on ontology models prescribed in the ontology engineering field is proposed. Finally, an alignment scheme is drawn to correlate the encoded ESOM with the proposed eGovernment development framework phases. The aims of the study are twofold: (1) providing eGovernment developers, particularly those from the developing world with guidelines for adopting existing semantic ESOM in their eGovernment projects, and (2) strengthening the adoption of semantic technologies in eGovernment processes. The main contribution of the study is the investigation, analysis and correlation of existing ESOM with a proposed semantic-driven eGovernment development framework phases, which provides methodologies and techniques for the iterative adoption of ESOM in other eGovernment projects within the eGovernment development community.

Keywords: eGovernment, ontology models, correlation, eGovernment development framework, semantic technologies

1. Introduction

As eGovernment evolves in maturity, heterogenous systems of government departments and agencies need to be integrated and interoperate to provide a seamless services delivery to citizens. In view of the current state of methodological approaches for eGovernment development, semantic technologies provide the best solutions for achieving seamless services delivery in eGovernment (Sanati and Lu 2007; Muthaiyah and Kerschberg 2008). These semantic-based solutions consist of describing, composing, mapping and merging eGovernment services (e-services) using ESOM (Apostolou et al. 2005a, 2005b; Sabucedo and Rifon 2006; Puustjarvi 2006; Xiao et al. 2007; Chen et al. 2008; Gugliotta et al. 2005; Sanati and Lu 2009; Sabucedo et al. 2010). The concern of this paper is the fact that these ESOM do not correlate with eGovernment development phases nor are detailed guidelines provided to facilitate their repeatability in eGovernment projects within the eGovernment development community. This paper establishes a correlation between existing ESOM and eGovernment development phases. Firstly, ESOM developed in various eGovernment researches and projects are investigated and encoded. Thereafter, a semantic-driven eGovernment development framework based on ontology models prescribed in the ontology engineering field is proposed. Finally, an alignment scheme is drawn to correlate the encoded ESOM with the proposed eGovernment development framework phases. The aims of the study are twofold: (1) providing eGovernment developers, particularly those from the developing world with guidelines for adopting existing semantic ESOM in their eGovernment projects, and (2) strengthening the adoption of semantic technologies in eGovernment processes. The main contribution of the study is the investigation, analysis and correlation of existing ESOM with a proposed semantic-driven eGovernment development framework phases, which provides methodologies and techniques for the iterative adoption of ESOM in other eGovernment projects within the eGovernment development community.

The rest of the paper is organized as follows. Section 2 conducts a review of existing ESOM and the ontology models prescribed in the ontology engineering field, as well as their semantic alignment. The proposed semantic-driven eGovernment development framework is presented in section 3. Section 4 describes the correlation scheme of the ESOM with eGovernment development phases. A discussion is carried out in section 5 and a conclusion is drawn in the last section.

2. Methodology

Figure 1 describes the correlation process. Firstly, a literature review is carried out in both eGovernment and ontology engineering domains to identify existing ontology models. As a result, eGovernment specific ontologies (eGovernment domain) and prescribed ontologies (ontology engineering domain) are identified. Thereafter, a semantic alignment of both categories of ontologies is established. The alignment result and a proposed eGovernment development framework are used to correlate the eGovernment specific ontologies with the development phases.

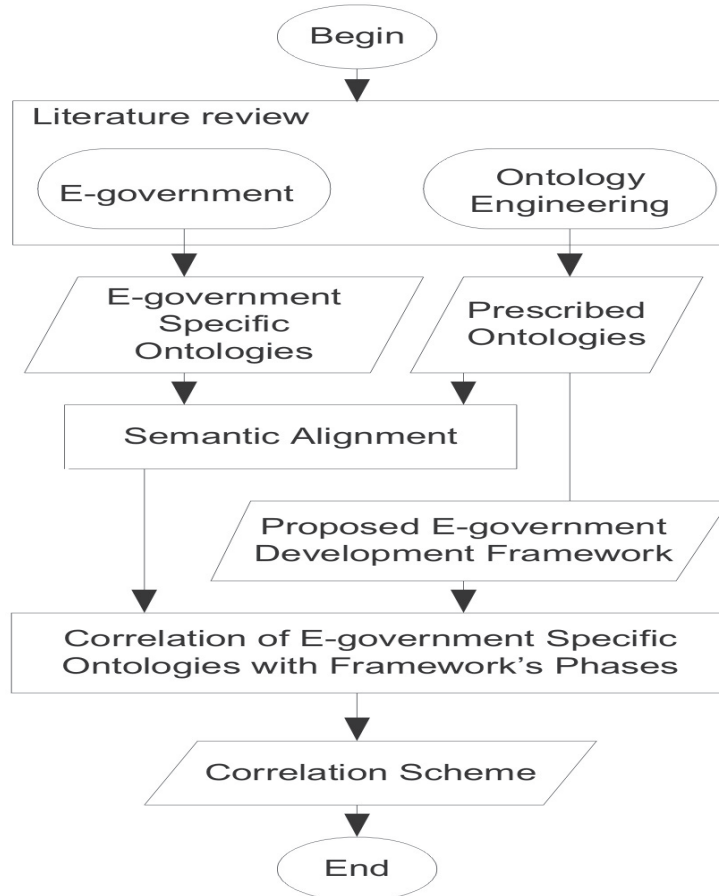


Figure 1: Flowchart of the correlation process of existing ESOM with eGovernment development phases

2.1 Background on existing ESOM

There is no universal definition of ontology in the literature (Gomez-Perez and Benjamins 1999). The most commonly used definition was proposed by Gruber (1995). He defined ontology as an explicit specification of a conceptualization. A conceptualization is an abstract and simplified view of a domain of knowledge one wishes to represent for a certain purpose; the domain could be explicitly and formally represented using existing objects, concepts, entities and the relationship that exist between them (Gruber 1995). Ontology is widely used in disciplines such as computer science, software engineering, databases, artificial intelligence, and many more (Welly 2003; Calero et al. 2006). In these fields, developers use ontology to represent knowledge in a manner that can be automatically processed by computers. In eGovernment, ontology is being used to describe and specify e-services aiming at their easy composition, mapping, matching and merging for a seamless services delivery to citizens through one-stop portals (Wimmer 2002; Lee et al. 2009). Therefore, specialized ontologies are being developed to model government's structures, laws and regulations, service delivery processes, interactions between government and citizens, integration and interoperability processes, and the like.

Sanati and Lu (2009) use three kinds of ontologies namely: government ontology, regulatory ontology and service ontology to describe the e-services integration process. The ONTOGOV project (Apostolou et al. 2005a, 2005b) provides a platform which allows the composition, reconfiguration and evaluation of e-services using eight kinds of ontologies including legal ontology, organizational ontology, life-cycle ontology, domain ontology, service ontology, life-event ontology, profile ontology, and web service

orchestration ontology. Other solutions for services integration based on specific ontologies are proposed in Chen et al. (2008) and Gugliotta et al. (2005). Chen et al. (2008) propose a framework for services integration based on citizen ontology, domain ontology, and generic eGovernment ontology, whereas, Gugliotta et al. (2005) establish the mapping of legacy ontology, workflow ontology, service ontology, life-event ontology, and eGovernment domain ontology to a predefined eGovernment system reference model, aiming at achieving services integration and interoperability for One-Stop portals. The issue of services interoperability is further addressed by Sabucedo and Rifon (2006), Xiao et al. (2007) and Sabucedo et al. (2010) with specialized ontology models. Xiao et al. (2007) model the interoperability process using the eGovernment business ontology. Sabucedo and Rifon (2006) use the life-event ontology, variable ontology, and legal document ontology, developed in a semantic-based platform, to enable the interoperability of eGovernment services. A holistic solution for services interoperability is proposed by Sabucedo et al. (2010) based on the life-event ontology and document ontology. Another relevant literature by Puustjarvi (2006) proposes a process-document ontology model for the business process modeling in eGovernment.

None of the above researches and projects has established a correlation between the proposed ESOM and eGovernment development phases nor do they provide detailed guidelines to facilitate their repeatability in other eGovernment projects and strengthen the adoption of semantic technologies in eGovernment processes. This research establishes a correlation of the abovementioned ESOM with a proposed semantic-driven eGovernment development framework phases; which provides methodologies and techniques for the iterative adoption of ESOM in other eGovernment projects.

Table 1 summarizes the 26 existing ESOM presented above (see the third column of Table 1), the eGovernment issues they were used to address (see the second column of Table 1), as well as a brief summary of their purposes and/or roles in the eGovernment domain (see the fourth column of Table 1). In the third column of Table 1, the ESOM are also encoded to facilitate their later reference in this paper. Each eGovernment specific ontology model in the third column of Table 1 is encoded as EGovernment Ontology x (EO x); where x is a number between 1 and 26 inclusive. It is worth noting that some ESOM in Table 1 which are sharing the same name have been assigned different codes; this is due to the fact that in certain cases, the purposes and/or roles for which these ESOM were used are different from one author to another. The ontology models prescribed by the ontology engineering field are described in the next section.

2.2 Ontology models prescribed by the ontology engineering field

There is no universal classification of ontologies in the ontology engineering research domain. Several classifications of ontologies are provided in the literature (Mizoguchi and Ikeda 1995; Uschold 1996; Gangemi et al. 1999; Gomez-Perez and Benjamins 1999; Beck and Pinto 2003). However, two main criteria could be used to classify ontologies: the formality used and the nature of the domain of knowledge that the ontology is characterizing. The formality refers to the level of detail employed to create the ontology's vocabulary and specifies the meaning of terms. The domain of knowledge could be anything at all; it could refer to a domain such as medicine, geographic information system or eGovernment; it could also refer to an area of problem solving or knowledge representation language (Uschold 1996). A classification of ontologies according to the above criteria is as follows:

1. Formality

- Informal ontology (Uschold 1996; Gangemi et al. 1999): expressed either in natural language or in a semi-structured form of natural language.
- Semi-formal ontology (Uschold 1996): expressed in a formally defined language.
- Formal ontology (Uschold 1996): terms are meticulously defined with formal semantic, theorems and proofs.

2. Domain of Knowledge

- Domain ontology: characterizes domains such as medicine, geology, eGovernment, etc; provides vocabularies about the concepts within a domain and their relationships, the activities that take place in that domain, and theories and elementary principles governing the domain (Gomez-Perez and Benjamins 1999; Beck and Pinto 2003).

Table 1: Existing ESOM, eGovernment issues addressed, and purposes and/or roles

Authors	E-government Issues Addressed	Ontology Models	Purposes and Roles
Apostolou et al. (2005a, 2005b)	Services configuration, reconfiguration and evaluation	Life-event ontology [EO1]	- Classification of government services (health, defense, education, environment, etc.)
		Domain ontology [EO2]	- Describes concepts of the domain (type and structure of document)
		Legal ontology [EO3]	- Models the structure of legal documents (paragraphs, sections, amendments, etc.) - Captures the laws and regulations that govern public administrative services
		Organizational ontology [EO4]	- Models the structure of a government organization, its resources, its roles, etc.
		Life cycle ontology [EO5]	- Describes information flow and decision making process (design decision and the reason that motivate the decision) - Allows the modification, traceability and maintenance of services
		Service ontology [EO6]	- Describes service flow - Use domain ontology to define inputs outputs and life cycle ontology to define design decision and motivating reasons
		Profile ontology [EO7]	- Contains meta data of e-services (name, short description, version, status, date of creation, creator, etc) - Includes all the previously mentioned ONTOGOV ontologies
		Web Service Orchestration ontology [EO8]	- Allows the binding of services during execution
Sabucedo et al. (2010)	Interoperability	Life-event ontology [EO9]	- Describes a process accomplishable by a citizen with the public administration - Define semantic relationship between input document, scope and cost of the process
		Document ontology [EO10]	- Describes the semantic structure of a document - Semantic relationship is established between the document's header, body, section, and attachment
Xioa et al. (2007)	Interoperability	E-government Business Ontology [EO11]	- Creates share vocabulary of business process of government services - Defines a business process in terms of task, input, output, resource constraints, and logical relation with other businesses
Sabucedo & Rifon(2006)	Interoperability	Life-events ontology [EO12]	- Defines events that create transitions in the citizen's life (be born, get married, etc.)
		Variable status ontology [EO13]	- Defines status of a citizen that requires a particular treatment (professional status, official degrees, etc.)
		Legal document ontology [EO14]	- Defines the require document for citizens' transaction with public administration
Paustjarvi (2006)	Business process modeling	Process-document ontology [EO15]	- Defines the concepts of a government business process (task, input, output) - Defines semantic relationship between government business processes and documents
Gugliotta et al. (2005)	Integration and interoperability	Legacy ontology [EO16]	- Defines concepts and relations describing the laws and political knowledge defining the services
		Workflow ontology [EO17]	- Describes the workflow of specific services
		Service ontology [EO18]	- Semantic Web Services description of services
		Life-event ontology [EO19]	- Defines a hierarchy of topics, concepts and relations of life events
		E-government domain ontology [EO20]	- Describes public administration concepts including: organizational, legal, economic, business, information technology and end-user concepts
Sanati and Lu (2009)	Integration	E-government ontology [EO21]	- Describes government specific terms as technical, organizational, workflow, etc.
		Regulatory ontology [EO22]	- Models the laws and regulations that govern rules of composite services
		Service ontology [EO23]	- Describes services in terms of availability, type, profile, regulations and communication parameters for the run-time workflow construction
Chen et al. (2008)	Integration	Citizen ontology [EO24]	- Describes users of government portals - Makes e-services transparent to citizen
		Domain ontology [EO25]	- Describes department knowledge
		Generic E-government Ontology [EO26]	- Maps different domain ontologies

- Task/Method/Problem solving ontology: terms are specific to a particular task or problem solving methods (Uschold 1996; Gomez-Perez and Benjamins 1999); describe specific tasks or activities using the vocabulary specified in the domain ontology (Gangemi et al. 1999).
- Representation or Meta ontology: represented in an existing ontology language (Uschold 1996); written in description logic (Beck and Pinto 2003); uses the syntax employed to formalize knowledge in knowledge representation paradigms; reusable across domains (Gomez-Perez and Benjamins 1999)

In the remaining sections of this work, we will refer to the above types of ontologies defined in the ontology engineering field as Prescribed Ontology Models (POM). The next section establishes the semantic alignment of ESOM in Table 1 with the POM.

2.3 Semantic alignment of existing ESOM with POM

To semantically align ESOM with the POM, we have formulated three propositions which broadly define the characteristics of the POM. Then, an eGovernment specific ontology model is aligned to a prescribed ontology model i.e. it belongs to the class of ontologies formed by the prescribed ontology model, if its purposes and/or roles described in Table 1 satisfy the corresponding proposition. Let's consider an ontology *O*. The propositions are formulated as follows:

- P1: *O* describes the entities of a domain of knowledge and the relationships between them; these entities may have a physical, abstract or moral representation.
- P2: *O* describes the processes of a domain of knowledge; it describes specific tasks or activities needed to carry out the processes using the domain concepts.
- P3: *O* describes either the entities or processes of a domain of knowledge and it is formally written in such a way that it can be processed by a computer.

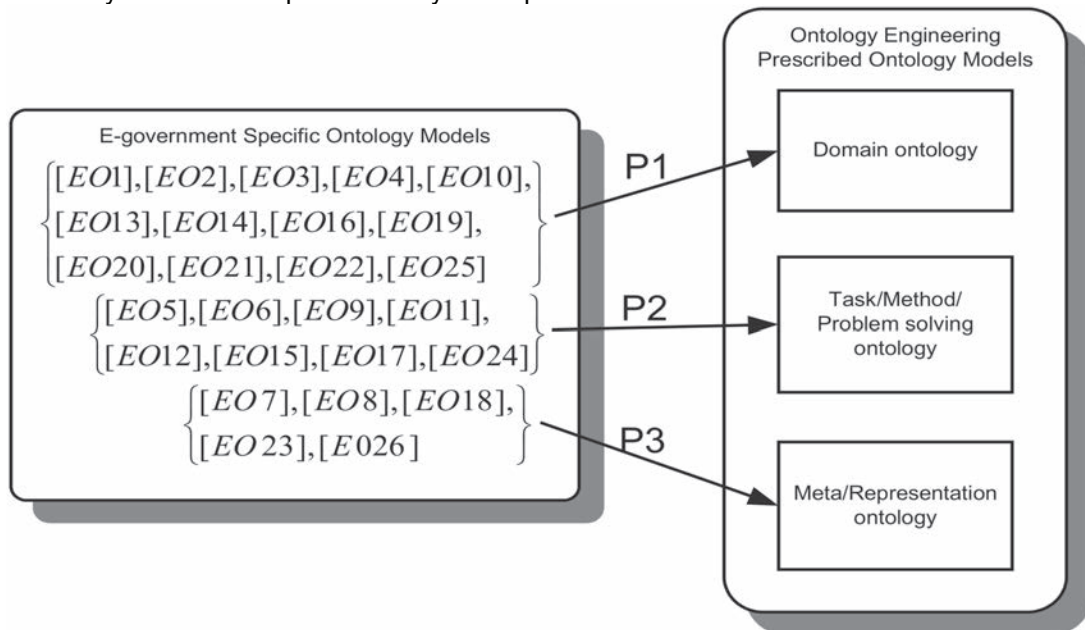


Figure 2: Alignment of ESOM with POM

After having defined the propositions, the semantic alignment is carried out manually by analyzing the purposes and/or roles of each eGovernment specific ontology model in Table 1 and finding out which of the above propositions is satisfied by these purposes and/or roles. The result of the semantic alignment is provided in Figure 2. The ESOM are represented using the encoding established in the third column of Table 1. Furthermore, ontology models which purposes and/or roles satisfy a common proposition are grouped into a set (see the left part of Figure 2). The proposed semantic-driven eGovernment development framework is presented in the next section.

3. Proposed semantic-driven eGovernment development framework

In Fonou-Dombeu and Huisman (2010), we have proposed a three phase semantic-driven eGovernment development methodology framework amalgamating eGovernment development methodological features from the public administration, software engineering and Semantic Web domains. Figure 3 depicts the architecture of the proposed semantic-driven eGovernment development methodology framework.

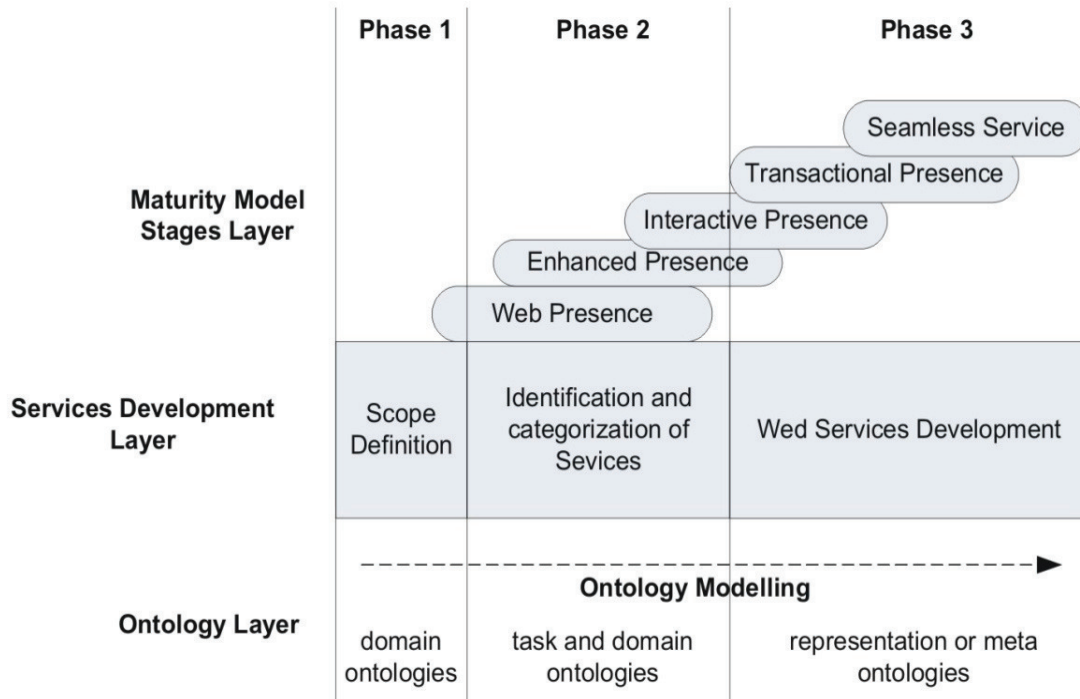


Figure 3: The proposed three phase eGovernment development framework aligning the United Nations maturity model stages with ontologies

A complete description of the specification of the proposed methodology framework in Figure 3 is out of the scope of this research; more information could be found in Fonou-Dombeu and Huisman (2010). This research provides a brief description of the framework and emphasizes on the semantic alignment of the development phases with the ESOM.

In the proposed methodology framework in Figure 3 we present a new generation of eGovernment applications development methodology as a system with three layers namely: maturity model stages layer, service development layer and ontology layer. The maturity model stages layer is the domain of public administrators who provide a certain number of stages for eGovernment development as well as guidelines for the planning and implementation of eGovernment systems. The service development layer in the middle, falls under the software engineering domain and provides tools and platforms for the analysis, design and effective implementation of e-services; in particular, we are more interested at this layer by the agile software development techniques which would allow fast development of e-services, iterative and incremental development, constant review of e-services requirements as well as constant prototyping during development. The ontology layer is the semantic-based layer which prescribes the use of semantic technologies as ontologies for the modelling and specification of e-services at each stage of development to facilitate their integration, maintenance and interoperability at advanced stages of development.

More importantly, the proposed methodology framework in Figure 3 provides three phases for eGovernment development namely: scope definition, identification and categorization of services, as well as Web Services development. At each phase of the framework is aligned a POM for the semantic description and specification of eGovernment services at that particular phase. The aim of this study being to correlate the ESOM with the three phases of the proposed framework in Figure 3, we present in the next section the correlation scheme of the ESOM with the framework phases.

4. Correlating ESOM with the proposed eGovernment development framework phases

We recall that the proposed eGovernment development framework in Figure 3 is based on ontology models prescribed in the ontology engineering field. It can be noticed that these prescribed ontology models represented at each phase of the framework, under its ontology layer, are the same as the POM mentioned earlier in this research. Then, correlating the ESOM with the framework phases will consist of establishing an alignment of the POM in Figure 2 with those in Figure 3. To this end, the following propositions have been formulated:

P4: A prescribed ontology model is aligned to one or many phases of the proposed eGovernment development framework.

P5: If a prescribed ontology model is aligned to a phase of the framework, then, the ESOM which are aligned to it are also aligned to that same phase of the framework.

In light of the above propositions, the correlation of ESOM with the proposed eGovernment development framework phases in Figure 3 is provided in Figure 4. Figure 4 shows that all the ESOM classified as domain ontologies in Figure 2 are aligned to the first and second phases of the proposed framework. Similarly, all the ESOM classified as task and Meta ontologies respectively are aligned to the second and third phases of the framework respectively. More information on the structure of the framework phases is given in Figure 3.

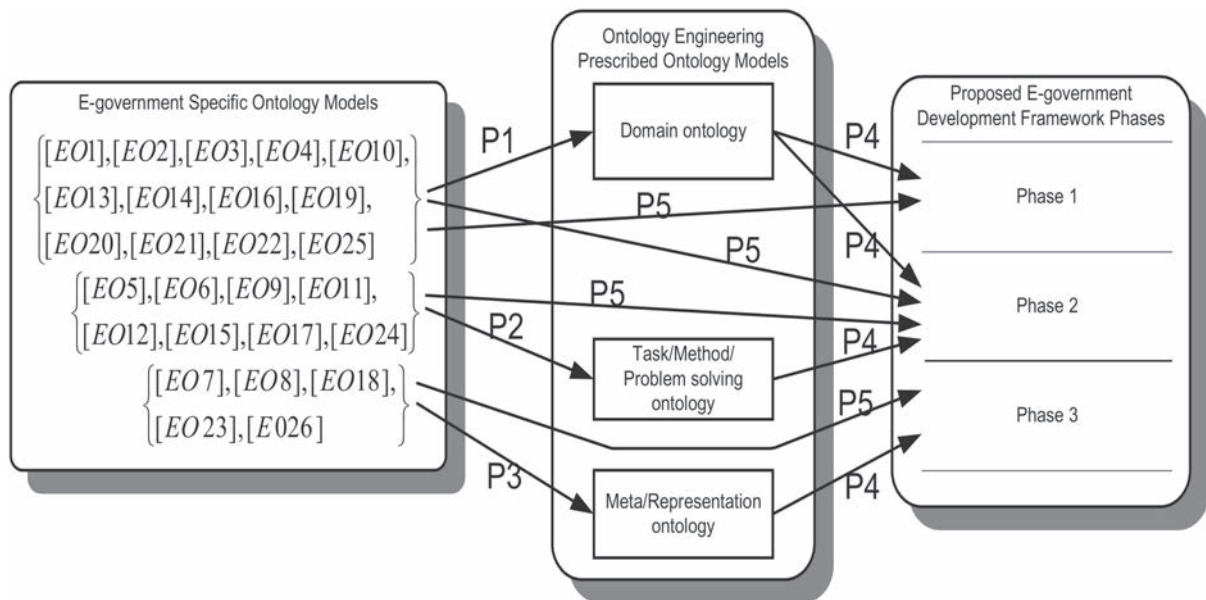


Figure 4: Correlation scheme of ESOM with proposed eGovernment development framework phases

5. Discussion

This research has investigated, analysed and correlated specific eGovernment ontology models that are being developed in various researches and projects, with the phases of our proposed eGovernment development framework (see Figure 3). The correlation scheme in Figure 4 has aligned thirteen ESOM to the first phase of the framework namely: scope definition; at this phase of eGovernment development, the aligned ESOM will mainly be used to describe and specify the government business domain. In particular, the ESOM at the first phase of the framework will be employed to model government structure and services ([EO1], [EO4], [EO16], [EO20], [EO21], [EO25]), describe government documents, laws and regulations that govern government services ([EO2], [EO3], [EO10], [EO14], [EO22]), describe citizens' status ([EO13]), and concepts related to the interaction of citizens with government ([EO19]). Eight ESOM as well as some of the ESOM aligned to the first phase, are aligned to the second phase of the framework namely: identification and categorization of services; at this phase of the framework, the ESOM will serve to model government processes ([EO5], [EO9], [EO11], [EO15]), describe e-services flows ([EO6], [EO17]) and transitions of citizens' life ([EO12], [EO24]). At the third phase of the framework, five ESOM are aligned; they are formally written with Semantic Web technologies ([EO18])

and provide mechanisms for automatic composition, mapping, matching and merging of e-services ([EO7], [EO8], [EO23], [EO26]) and facilitate their integration and interoperability.

As mentioned previously, the researches investigated to identify the ESOM described above do not provide detailed guidelines on how one can repeat the proposed ESOM in other eGovernment projects. This study has overcome this weakness by aligning the various ESOM to the ontology models prescribed in the ontology engineering field. This is a great opportunity to eGovernment developers as the wider range of methodologies and techniques for building ontologies (Uschold 1996; Fernandez-Lopez 1999; Beck and Pinto 2003; Calero et al. 2006) which are available in the ontology engineering domain could be exploited for a widespread use of the ESOM in future eGovernment projects. Furthermore, the correlation of the proposed ESOM with the phases of the proposed eGovernment development framework presented above, provide eGovernment developers with a stepwise based mechanism for the iterative adoption of ESOM in future eGovernment projects.

6. Conclusion

The study reviews researches focusing on semantic eGovernment and published between 2005 and 2010 inclusive. As a result, 26 eGovernment specific ontology models were identified, analysed and correlated with a proposed semantic-driven eGovernment development framework phases; this provides methodologies, techniques and mechanisms for the iterative adoption of the proposed eGovernment specific ontology models in other eGovernment projects within the eGovernment development community.

The study reveals that various authors are proposing eGovernment specific ontology models under the same name, but with different purposes/roles. Then, it would be useful to normalize the semantic ontology models characterizing the eGovernment domain in the near future, so as to prevent inconsistency and confusion in the semantic eGovernment development community.

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CHAPTER VIII

Conclusion and Future Work

8.1. Conclusion and Contributions

The motivation for this research was the need for a unified and comprehensive methodology that provides structured guidelines for the planning and agile semantic-driven development of e-government systems. Initially, we defined the following objectives that could be achieved to develop such a methodology.

- 1) Critically analyse existing ontology engineering techniques,
- 2) Identify appropriate kinds of ontologies for e-government services description and specification,
- 3) Develop a framework for agile application development in e-government,
- 4) Develop a framework for ontology development in e-government,
- 5) Identify software platforms for ontology development in e-government,
- 6) Conduct a detailed case study of semantic ontology development in e-government processes.

The first and second objectives were achieved by reviewing the literature in the ontology engineering field and identifying various kinds of prescribed ontologies as well as the methodologies for building them.

Our contribution has been to analyse and correlate the existing kinds of ontologies with the stages and phases of e-government development, so as to enable the semantic description and specification of e-government services at various circumstances and phases of e-government development (see Chapter 2).

The third objective was achieved by investigating the methods and techniques currently used for e-government implementation worldwide; it was discovered that maturity models, software engineering and Semantic Web techniques are being used for the planning, design and implementation of e-government systems. Then, the advantages and disadvantages of each of these techniques in e-government development were further investigated; as a result, it was found that: (i) maturity models provide various stages for e-government development as well as web features or levels of sophistication of e-government systems at each stage of development; however, the specification of the maturity models' stages lack design

guidelines and tools for the effective design and implementation of the prescribed web features, (ii) in the software engineering and Semantic Web domains, e-government development is not done according to prescribed stages or phases; which might make it extremely difficult to plan and implement a semantic-driven e-government project with these techniques, given the complex nature of the public administration system with several departments and agencies, thousands of legislations and operating procedures, added to the high number of technologies needed. Finally, it was discovered that little guidelines were provided in the semantic based e-government researches and projects to enable the repeatability of the proposed ontology based solutions in other e-government projects.

Our contribution has been to amalgamate the methodological features from the maturity models, software engineering and Semantic Web domains to design and specify a semantic-driven methodology framework for e-government systems development (see Chapter 2). Furthermore, we investigated the agile software development methods, understood their principles and used them to design and specify the business process model of the proposed methodology framework which enables the incremental and iterative semantic-driven planning and implementation of e-government systems (see Chapter 2). This work was published in the e-government community and appreciated as being useful and innovative (Fonou-Dombeu and Huisman, 2010a, 2011d).

In particular, the business process model of the methodology framework provides structured guidelines for the iterative and incremental planning, design and implementation of one-stop e-government portals, which is one of the key and challenging priorities in e-government development. Therefore, the proposed methodology framework presented in Chapter 2 is a useful tool for e-government systems development; particularly in developing countries where little progress has been made towards the development of one-stop e-government portals for seamless services delivery to citizens.

The fourth, fifth and sixth objectives were achieved by further specifying the semantic modelling and specification of the contents of e-government systems at various phases of the methodology framework (see Chapter 3 to 6). This was done by developing at various layers (conceptual, semi-formal and formal), a case study of government domain ontology using ontology building methodology, modelling and representation techniques including Description Logic and UML, and state-of-the-art Semantic Web ontology languages and platforms including RDF, OWL, Protégé and Java Jena API.

Our contributions at this point are threefold: (i) The application of an ontology building methodology for the development of a government domain ontology from a government

service domain (see Chapter 3 and 4); this work was published in the computing community (Fonou-Dombeu and Huisman, 2010b), in the software engineering and applied computing community (Fonou-Dombeu and Huisman, 2011f) and in the Semantic Web community (Fonou-Dombeu and Huisman, 2011g), (ii) The design and specification of a framework for the systematic generation of domain, semi-formal and formal ontology models in e-government projects (see Chapter 6); this work was published in the digital society community (Fonou-Dombeu et al., 2011a), (iii) The combination of ontology building methodologies and Semantic Web platforms for e-government domain ontology development (see Chapter 5); this work was published in the Semantic Web community (Fonou-Dombeu and Huisman, 2011b).

Beside the abovementioned contributions made from the investigation of our key objectives, we find it of utmost importance to align various e-government domain specific ontology models that are being proposed in various e-government researches and projects with the phases of our proposed methodology framework. To this end, the existing e-government specific ontology models (ESOMs) being used in various e-government researches and projects for the semantic description and specification of various aspects of e-government services delivery (government documents, laws and regulations, government structures and processes, life events of citizens with government, software processes, etc.) were investigated. In total, 26 ESOMs representing the state-of-the-art of semantic modelling and specification of e-services in the e-government domain were identified.

Our contribution has been to draw and specify a correlation scheme of the ESOMs with the phases of our proposed methodology framework to enable the repeatability of these ESOMs in other e-government projects (see Chapter 7); this work was published in the e-government community (Fonou-Dombeu and Huisman, 2011e).

The correlation scheme of ESOMs with the methodology framework phases is a useful tool for the semantic e-government development community. In fact, each phase of the proposed methodology framework includes ontology model(s) prescribed in the ontology engineering field; this provides e-government developers with opportunities to exploit existing ontology building methodologies to repeat the ESOMs in any circumstance or phase of e-government systems development. Furthermore, the business process model of the methodology framework describes the mechanisms and techniques for the iterative and incremental adoption of these existing ESOMs in other e-government projects. This might strengthen the adoption of Semantic Web technologies in the e-government community and promote the development of e-government services that can be semantically integrated and

interoperated towards one-stop e-government portals for seamless services delivery to citizens.

Finally, in Chapter 3 and 4 a framework adopted from the Uschold and King (1995) ontology building methodology was used to develop a government domain ontology.

Our contribution has been the practical application of an ontology building methodology for the development of domain ontology. This work may be useful in the ontology engineering field as the framework employed could be easily repeated in other domain of knowledge to develop domain ontology; this work was published in (Fonou-Dombeu and Huisman, 2010b, 2011f, 2011g).

8.2. Future Work

We identify the following directions for future research: storage and query of domain ontology, ontology development under the .NET platform, standard ontology for e-government and integration of e-government domain ontology.

- **Storage and query of domain ontology:** Semantic Web ontology language representation of domain ontology specifies and describes semantically the knowledge of the domain. However, this knowledge can only be useful if it is deployed in a real world application. Therefore one of the future direction in which this work can be improved is to investigate suitable platforms and mechanisms for the storage and query of e-government domain ontology.
- **Ontology development under the .NET platform:** Microsoft .NET platform provides useful tools for easy and fast development of web-based applications. Furthermore, the .NET platform is amongst the most widely used platforms in the software development community as well as in Information Technology programmes in academic institutions. However, current development of Semantic Web is largely based on open-sources platforms. Therefore, investigating the development of e-government domain ontology under the .NET platform would improve this study.
- **Standard ontology for e-government:** Currently, there is no standard way of developing ontology in the ontology engineering field. The same applies in e-government where various ontology models are being developed with the same name to serve different roles/purposes. A possible future direction of this research would

consist of investigating a standard for ontology modelling of the public administration system and processes.

- **Integration of e-government domain ontology:** Integrating autonomous and heterogeneous systems remain challenging in e-government. The semantic development of these systems is part of the solution to this problem as demonstrated in this study. However, further studies need to be carried out to develop tools, mechanisms and algorithms for integrating semantic ontology models from different government service domains.

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