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

Jean Vincent Fonou Dombeu[1,2]
[1]Department of Software Studies
Vaal University of Technology
Vanderbijlpark, South Africa
Email: fonoudombeu@gmail.com

Magda Huisman[2]
[2]School of Computer, Statistical and Mathematical Sciences
North-West University
Potchefstroom, South Africa
Email: Magda.Huisman@nwu.ac.za

Zygmunt Szpak[3]
[3]School of Computer Science
The University of Adelaide
Adelaide, Australia
Email: zygmunt.szpak@adelaide.edu.au

***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 hierarchal 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

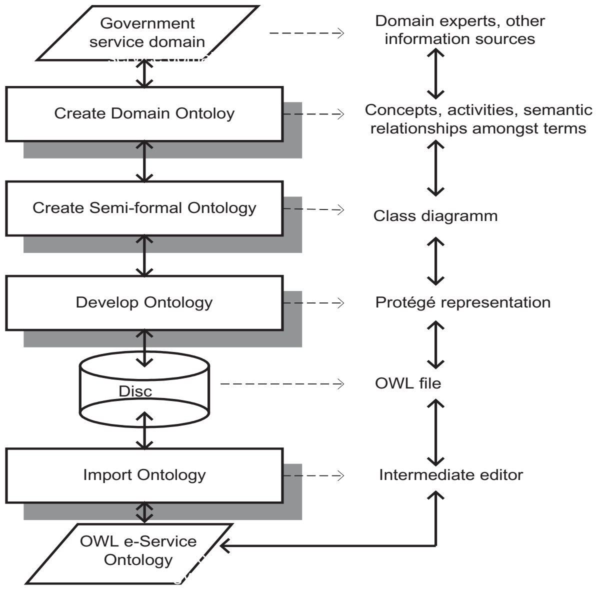

Fig. 1. Framework for OWL Ontology Generation

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 version of the ontology from the file. To fulfil the aim of this paper which is to provide e-government developers with a step-by-step guideline for generating semantic model OWL ontologies from e-government service domains, a real-life case study illustrating the steps of the framework provided in Figure 1 is conducted in the next section; each subsection corresponds to a step of the framework in Figure 1 from top to bottom.

VI. Case Study

A. E-government Service Domain

The case study used in this paper was motivated by the fact that, in developing countries and in Sub Saharan Africa (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 and include infrastructure development, water supply and sanitation, education, rural development, health care, ICT infrastructure development and so forth. Thus, we thought that an e-government web application that could interface all the activities related to development projects implementation in a SSA country could bring tremendous advantages; particularly, such a web application would improve the monitoring and evaluation of projects and provide transparency, efficiency and better delivery to populations. In [22], we have proposed an ontology support model for such a web-based e-government application. We evaluated case studies of development projects implementation, consulted domain experts including municipalities and non-governmental organizations employees and academic members, and reviewed publications in related fields including project management, project monitoring and evaluation, and capacity building [22]. Thus, a conceptual/domain ontology of development projects monitoring (OntoDPM) in a developing country was developed [22]. The next section presents the OntoDPM.

B. Create Domain Ontology

The ontology engineering field has established various kinds of ontologies; an exhaustive list of these ontologies could be found in [18]. One of the most commonly used of these ontologies is the conceptual/domain ontology. A domain ontology characterizes domains such as medicine, geology, e-government, and so on; it provides vocabularies about the objects and concepts within a domain and their relationships, the activities that take place in that domain, and theories and elementary principles governing the domain [12].

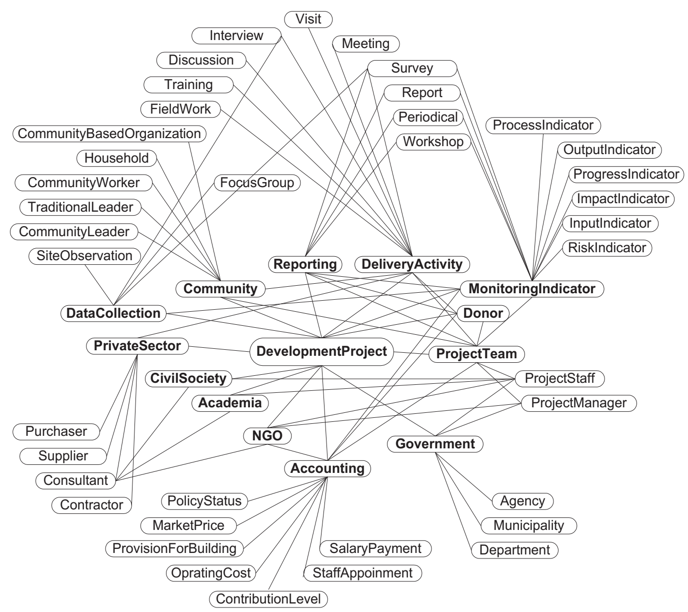

Fig. 2. OntoDPM Domain Ontology

In [22], we used a five step framework adopted from the Uschold and King [14] ontology modelling approach to represent the OntoDPM domain ontology as in Figure 2. 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. The semi-formal representation of the OntoDPM is provided in the next section.

C. Create the Semi-formal Ontology

Based on the OntoDPM in Figure 2 we designed the class diagram of the ontology. The classes, inheritance structure and the class instances are provided in Table 1. The classes in Table 1 were constructed by identifying entities and instances in the OntoDPM and categorizing relationships between entities

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 sucessfully. Figure 6 and Figure 7 show the imported OWL ontology in JCreator and Microsot 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

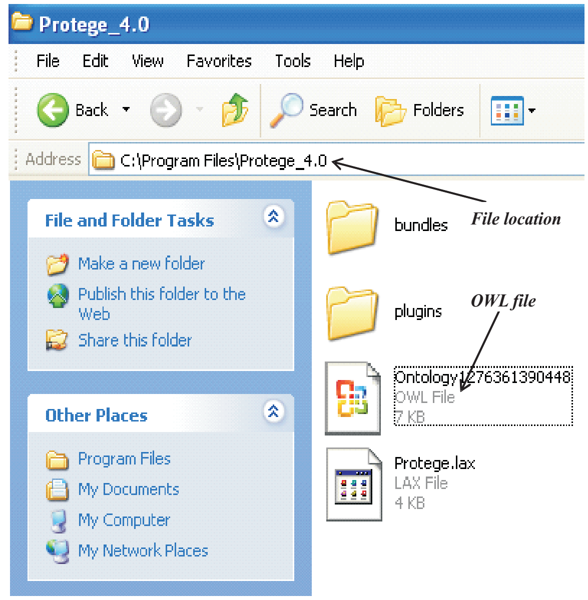

Fig. 4. OWL File and Location onto the Disc

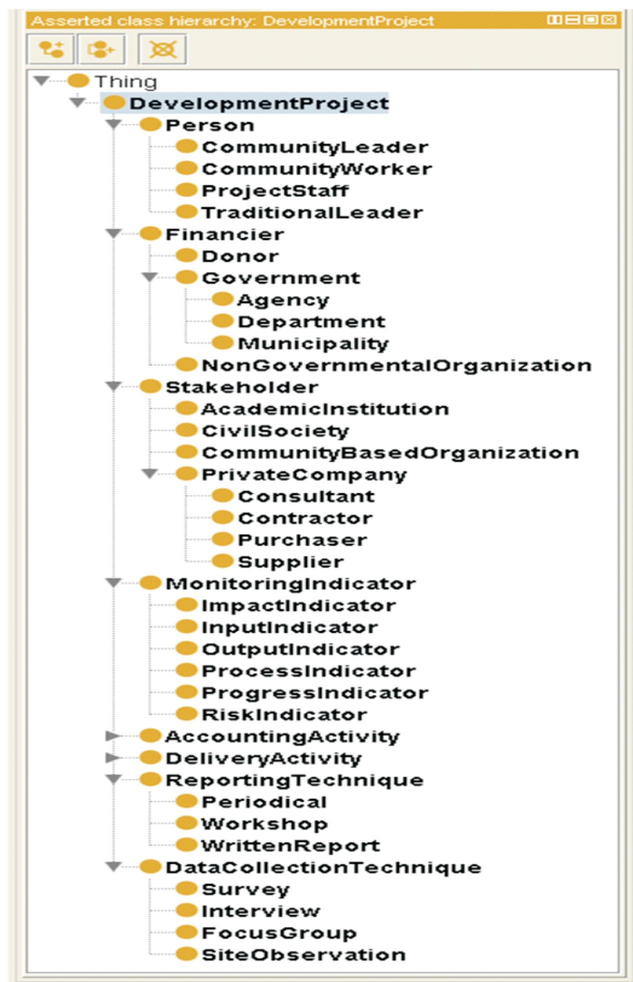

Fig. 5. Protégé Version of the OntoDPM

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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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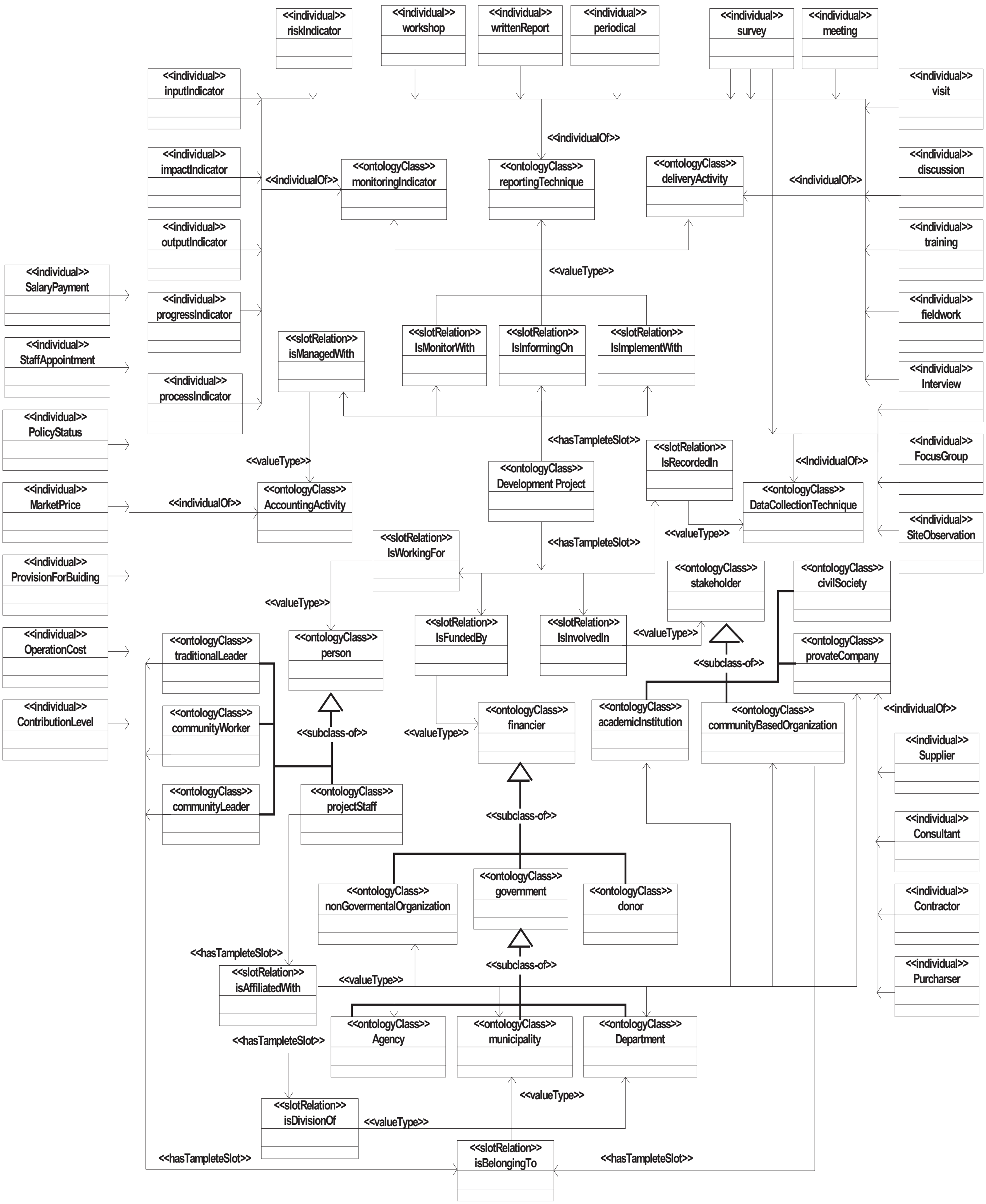

Fig. 3. Semi-formal UML Representation of the OntoDPM