Integrated Data Model Development Framework for the Architecture Descriptions

Mye Sohn[1], Saerom Kang[1], and Hyun Jung Lee[2*]
[1]Sungkyunkwan University, Suwon, South Korea
{myesohn, sr6435}@skku.edu
[2]Yonsei Institute of Convergence, Technology, Incheon, South Korea
hjlee5249@gmail.com

Abstract

One of the main pillars of the Department of Defense Architecture Framework Ver. 2.0 (DoDAF 2.0) is Meta-Model, named DM2. It defines data structure that facilitates understanding of the use of data within an architecture document and ensures sharing and reusing of architectural data across the architectures. It is still difficult to develop the data model for the architectures even though the DoDAF 2.0 is preparing supplementary tools for supporting the data model development. To reduce the difficulties, we propose an I2D2 framework (Integrated and Intelligent Data model Development framework) with an I2D2 Ontology. The primary goal of the I2D2 framework is identification of explicit and implicit associations which exist between/among the DM2 terms required to describe a set of the viewpoints for the architectures. To achieve the goal, we develop the I2D2 Ontology that is overarching and comprehensive tool enabling the development of the integrated data model for the architecture descriptions. In the experimental section, we implement our prototype system and demonstrate the performance of our framework via case studies.

Keywords: DoDAF 2.0, Architecture Framework, Data model, Ontology, Defense

1 Introduction

The two pillars of the Department of Defense Architecture Framework Ver. 2.0 (DoDAF 2.0) are Viewpoints organized by various DoDAF-described Models (also referred to as Models or Views) and Meta-Model [4]. The DoDAF-described Models are means of the abstracting essential information the various stakeholder communities need with a various ways like picture, graph, table, diagram, and/or ontology. The Meta-Model, or more specifically DoDAF Meta-Model (DM2) defines the “vocabulary” of DoDAF as the basis of the DoDAF 2.0. It defines data structure that facilitates understanding of the use of data within an architecture document and ensures sharing and reusing of architectural data across the architectures. The DM2 consists of three levels of data models such as the Conceptual Data Model (CDM), the Logical Data Model (LDM), and the Physical Exchange Specification (PES) [4]. Among them, the LDM description provides the essential aspects of the standard terminologies or concepts used in the DoDAF 2.0. It organizes into ‘Data Groups’ that are defined as semantically related concept clusters. Each Data Group contains a set of Concepts (classes), Associations (relationships), and Attributes that are required to represent the structure of the Data Groups. As depicted in Table 1, a series of the Data Groups are closely related to the Viewpoints.

To develop architecture for the specific purpose, the system architects and analysts, first and foremost, should determine a set of viewpoints that are required to describe the architecture. As a next step,

Journal of Internet Services and Information Security (JISIS), volume: 4, number: 4 (November 2014), pp. 91-102

*Corresponding author: Yonsei Institute of Convergence Technology, School of Integrated Technology, Yonsei University, 162-1, Songdo-dong, Yeonsu-gu, Incheon, Korea, Tel: +82-10-5266-5249

Viewpoint	DM2 Data Group (Principle Architectural Constructs)	DM2 Data Group (Supporting Architectural Constructs)
All Viewpoint	Resource Flow, Data and Information, Project	-
Capability Viewpoint	Performer, Resource Flow, Capability, Services, Project, Goals	-
Data and Information Viewpoint	Resource Flow, Data and Information,	
Operational Viewpoint	Performer, Activity, Resource Flow, Training/Skill/Education	Rules
Project Viewpoint	Performer, Resource Flow, Capability, Project, Goals	-
Service Viewpoint	Performer, Capability, Project, Training/Skill/Education	Rules, Measures, Location
Standard Viewpoint	Performer, Resource Flow, Services, Training/Skill/Education	Rules
System Viewpoint	Performer, Capability, Services, Projects, Training/Skill/Education	Rules, Measures, Location

Table 1: The relationship between viewpoints and DM2 Data Groups (Reshuffle the DoDAF 2.0)

s/he determines and collects data required to support the identified viewpoints. Needless to say, the data should be collected and organized according to the guidance of the DM2 Data Groups. So in a nutshell, the architecture should be described by different combinations of the viewpoints depending on the purpose. Furthermore, the architecture has to have the data in conformance with a set of the Data Groups according to the combination of the viewpoints. However, unfortunately, the Data Group is designed and developed for a specific purpose like Performer, Activity, or Resource Flow even though the architecture requires an integrated Data Group constructs for the combination of the viewpoints.

To support the system architects' and analysts' understanding the Data Groups, DoDAF 2.0 is preparing supplementary tools like the MS Excel file and the HTML-based ontology. Even though the supplementary tools for the DM2 specify relationships between the Models and DM2 vocabularies including the Data Groups and associations among the Data Groups, the tools cannot support the development of integrated Data Group constructs for the architecture. After all, the system architects and analysts have to shoulder the burdens on an integration of the Data Groups for the architecture. To reduce such burdens, we propose Integrated and Intelligent Data model Development framework for the architecture descriptions (hereafter, we called I2D2 framework). The backbone of the I2D2 framework is ontology that is defined as a collection of set of concepts, their definitions and the relationships among them represented in a hierarchical manner [9]. The I2D2 Ontology is overarching and comprehensive tool enabling the development of the integrated data model for the architecture descriptions. It can query the explicit concepts and the associations among the concepts and furthermore, it can perform the rule-based reasoning to derive the implicit concepts and the associations that are required to describe the architecture. In this light, the rule-based reasoning is another backbone of the I2D2 framework. Based on two backbones, we implement the prototype system.

This paper is organized as follows. The next section discusses related works. Section 3 and 4 describe overall architecture of the I2D2 framework and the data model ontology, named I2D2 Ontology. In Section 5, we demonstrate prototype system for the I2D2 framework and show the performance of our system through several case studies. Also, we discuss the security issues related to the DoDAF 2.0 in Section 6. Finally, Section 7 puts forth the conclusions and suggests further research in connection with the proposed framework.

2 Related Works

DM2 is defined as a formal ontology that provides semantically related concepts or elements into a common set of data types and define their associations and attributes [14]. It is core element to achieve the data-centric vision of the DoDAF 2.0. However, it is very difficult to develop the consistent and complete data model for the architecture description because traditional DM2 is provided with documents and/or HTML-based data model ontology [8, 17]. Although the ontologies contain the links among Concepts, Associations, and Attributes, they are not still support the data modeling procedures that can infer the explicit and implicit relationships among Concepts, Associations, and Attributes. To solve the problem, [14] provides a novel executable architecting approach transforming DM2 to executable model. [20] proposes the executable evaluation process based on DM2. In addition, to improve the DM2, Handley [7] incorporates the NATO Human View in the DM2.

Ontology is a best tool to help understanding of the DM2 for the stakeholders at the all levels. The values of the ontology have been proven by the DM2 and M3 (MODAF Meta Model) [8, 17]. The DM2 and M3 are devised to maintain the consistency among Concepts, Associations, and Attributes to be used for the development of the architecture descriptions [13]. In addition, ontology is applied to support the architecture development processes. [11] devises the ontology to support the development of the semantics-applied architecture frameworks. They adopt the ontology to enhance understanding and communication between humans and systems. Chen and Pooley [2] build a meta-model using the BWW (Bunge-Wand-Weber) ontology and the Enterprise ontology, which can apply to develop the machine-processible Zachman framework. In addition, Kilpeläinen and Nurminen [19] develop the Genre-Based Ontologies as a conceptual base for the EA (Enterprise Architecture) descriptions. To share the meaning of FEA-RMs (Federal Enterprise Architecture Reference Models) among the stakeholders, the FEA-RMO (FEA-Reference Model Ontology) was developed [1]. FEA-RMO supports the queries to identify useful information in FEA documents and provides a guideline for direction or the scope of modeling. Arseniev [15] provided ontology-based EA for the management of the information systems of a university.

Many enterprise architecture frameworks including the DoDAF 2.0 do not adequately address security and furthermore, do not specify the tools and methodologies to develop the security-aware architecture description [6, 10, 18]. To solve the security issue, [5] suggests the methodology for integrating security into EA analyses, named SEAM (Secure Enterprise Architecture Methodology). Kärkkäinen [12] presents a cyber-security architecture that defines the tasks of the security elements at a functional level without introducing any new protocols or algorithms. Conkling and Hamilton [18] suggest a framework for modeling architectural security using the DoDAF, and Jalaliniya and Fakhredin [10] try integration of Enterprise Architecture and Security Architecture.

Even though some researchers argue that security is a nonfunctional or performance system requirement [3], we believe that security issues should be melted into the architecture development processes through the new Models and data models. So, in this paper, we propose the I2D2 framework that can support the overall processes of the architecture development including security. Its technical backbone is ontology. The I2D2 ontology is overarching and comprehensive tool enabling the development of the integrated data model for the architecture descriptions. It is differentiated from the existing ontologies by its capability of rule-based inference and for supporting the whole life-cycle of the architecture descriptions.

3 Procedural Architecture of the I2D2 Framework

As mentioned state, the primary goal of the I2D2 framework is identification of explicit and implicit associations which exist between/among the DM2 terms required to describe a set of the viewpoints for the architectures. To do so, we propose the procedural architecture for the I2D2 framework (Figure 1).

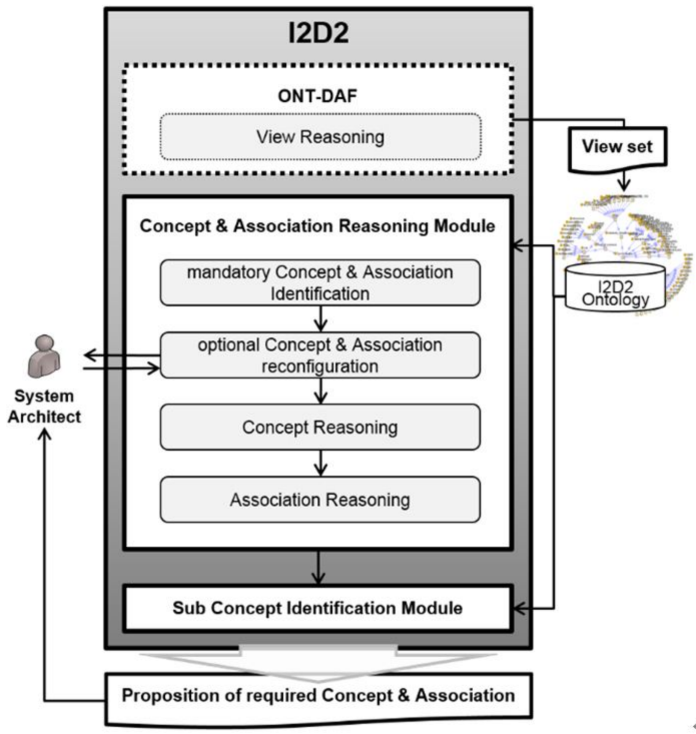

Figure 1: Procedural architecture of the I2D2 Framework

As depicted in Figure 1, the I2D2 framework is composed of the data model ontology and four modules such as ONT-DAF for view reasoning, Concept and Association Reasoning Module (CARM), Sub-Concepts Identification Module (SCIM), and User Interface (UI). The UI receives a set of viewpoints that are identified by the ONT-DAF from the system architects and/or analysts and returns the query or inference results to them through a graphic user interface (GUI). Before explaining the I2D2 ontology as a key component of the framework, we discuss the modules of the I2D2 framework.

3.1 ONT-DAF

The ONT-DAF (Ontology for DoDAF) is an intelligent system to support the development of the DoDAF 2.0-based architecture [13]. To do so, the ontology is composed of five classes (*TargetEA*, *Viewpoint*, *Data*, *Expression*, and *Reference*) and two properties that represent relationships between/among the classes (*has_view* and *has_data*). To execute the ONT-DAF, the system architects who are responsible for developing the architecture have to identify a set of the Models as input data depending on the purpose of the architecture. The ONT-DAF returns inference results to the system architects as follows: the derived Models that are related to the input Models and the sequence of the Model description. The I2D2 framework uses the inference results of the DoDAF as input data. For a full explanation of the ONT-DAF, refers to the above paper [13].

3.2 Concept and Association Reasoning Module (CARM)

In the DM2, the concepts and the associations for the whole Models are enumerated on matrix with MS Excel file type. To identify the concepts and the associations for a set of Models, the system architects explore and find the relevant concepts and the associations on the file. The process is time-consuming and error-prone. To resolve the problems, the I2D2 framework has the Concept and Association Reasoning Module (CARM). The CARM is a core module of the I2D2 framework. It automatically identifies the concepts and the associations that are required to develop the data model for the architecture. The CARM is triggered as soon as it receives a set of the Models for the architecture description from the ONT-DAF. The CARM performs three-phase tasks as follows.

Phase 1 Identification of the concepts and the associations for a set of Models: As mentioned state, the Model is described with a series of the terms that are composed of the concepts and the associations. At this time, some of terms are mandatory, and others are optional. This sub-module performs rule-based inference to identify the mandatory terms for a set of the Models. Illustrative rules with SWRL (Semantic Web Rule Language) are as follows.

Viewpoint(?view)^TargetEA(?view)^Mandatory_Concept(?View, ?C) → TargetEA(?view) ^need_Concept(?view, ?C)

Viewpoint(?view)^TargetEA(?view)^Mandatory_Association(?View, ?A) → TargetEA(?view) ^need_Association(?view, ?A)

The optional terms literally can be used for the Models or not. So, there is no need to infer the optional terms for the architectures. The I2D2 framework provides lists of relevant terms related to the mandatory terms through GUI. At this time, the lists of relevant terms are inferred from I2D2 Ontology that will be discussed in the next section.

Phase 2 Augmentation of the concepts for a set of Models: When the Phase 1 finished, the system architects and the analysts obtain not only a set of mandatory terms but also a set of optional terms. In addition, they have to trace some relationships that must be followed the things to describe the architectures. The things may have different kinds of relationships like tuple, couple, triple, quadruple, and quintuple[8]. However, the DODAF 2.0 adopts only tuple and couple relationships between the things [4]. The two types of relationships are named 'compliance relationship.' The following is a typical example of the compliance relationships in the DoDAF 2.0.

An *Association* has to have two 'Concepts.' And it is linked to the '*Concepts*' by the arcs, named '*Place1 (Domain)*,' and '*Place2 (Range)*.'

In particular, the above compliance relationship shall be called "association rule." After the mandatory terms, the optional terms, and the associations between them are fully identified, we should verify that they have complied with the association rules. If some associations that violate the association rule are found, the I2D2 framework adopts the following rule to fix it. There are two types of the violation of the association rule (depicted in Figure 2). The left pane of Figure 2 means that an association does not have a concept acts as range. Similarly, the right pane of Figure 2 violates the association rule due to missing a concept act as a domain.

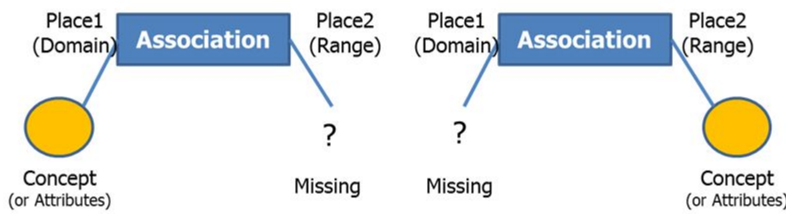

Figure 2: Procedural architecture of the I2D2 Framework

To remove the imperfect relationships among the terms, the I2D2 framework performs rule-based reasoning with SWRL (Semantic Web Rule Language) rules. The rules are illustrated as follows.

TargetEA(?view)^need_Association(?view, ?A)^Association(?A)^place1(?A,?C1)
→ TargetEA(?view)^extended_Concept(?view,?C1)

TargetEA(?view)^need_Association(?view, ?A)^Association(?A)^ place2(?A,?C1)
→ TargetEA(?view)^extended_Concept(?view,?C1)

Phase 3 Augmentation of the Associations for a set of Models: As a result of the execution of the Phase 2, the system architects and the analysts may obtain the new 'Concepts' that are not linked to Associations. In the Phase 3, the I2D2 framework tries to augment the Associations for 'Concepts' with incomplete relationships. Similar to the Phase 2, the rule-based inference based on the I2D2 Ontology is performed.

The I2D2 framework performs the Phase 2 and the Phase 3 repeatedly until the imperfect Concepts and Associations are removed. For instance, we assume the Concepts C1 and C2, and their Associations A1 and A2 are identified in the Phase 1. In the first round, the Concept C3 and the Associations A3 and A4 are inferred using the I2D2 Ontology. This has caused the imperfect Associations, named A1 and A4. To solve the problem, the I2D2 framework performs the second round. As a result, it finds new Concepts C4 and C5. And finally, the Associations A5 and A6 are identified. The problem-solving process is illustrated in Figure 3.

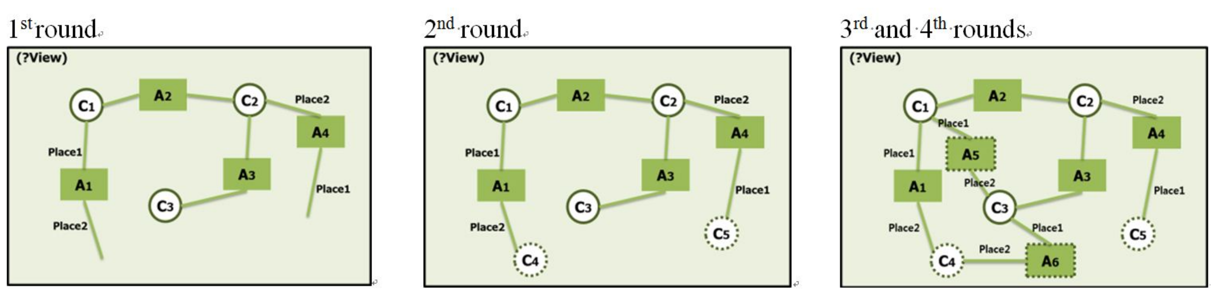

Figure 3: Illustration of problem-solving process

3.3 Sub-Concepts Identification Module (SCIM)

The Concepts in the DM2 are described in hierarchical structures. It contains a lot of 'hypo-hyper' relationships. To identify the hyper concepts of the Concepts that are found via an execution of the

CARM, the SCIM calls and uploads the I2D2 Ontology. As a next step, it traces the < rdf:ID = “generalization”> of a kind of ‘*owl:ObjectProperty*’ on the I2D2 Ontology. The <rdf:ID = “generalization”> consists of two ‘*owl:ObjectProperty,*’ named ‘*subType (hyper)*’ and ‘*superType (hypo).*’ Based on the hierarchical structures, the sub-concepts the system architects and the analysts want to use are inferred easily. The algorithm to find the sub-concepts is summarized in Figure 4.

```
cList: concept List
for( int i = 0, i < cList.size, i++) {
    if ( cList[ i ].subType.isEmpty() != True) {
      for ( int j = 0, j < cList[ i ].subType.size, j++) {
          cList[ i ].attribute[ j ] = subType[ j ];
        if ( attribute[ j ].subType.isEmpty() ==True) {
          for (int t = 0, t < cList.size, t++) {
            attribute[ j ] == cList[ t ];
            cList[ t ].remove; } } } } }
```

Figure 4: Algorithm to find the sub-concepts

4 Data Model Ontology

The I2D2 Ontology is composed of four classes (*Viewpoint*, *DataGroup*, *DataModel*, and *TargetViews*) and 22 properties that represent the relationships among the classes.

4.1 Class ‘*ViewPoint*’

Class ‘*ViewPoint*’ corresponds to the eight ViewPoints and their Models (Views) in the DoDAF 2.0. The main usage of the class ‘*ViewPoint*’ is to identify and infer ‘*Concepts*’ and ‘*Associations*’ for the architectures. The DoDAF 2.0 specifies the relationships of the ‘*ViewPoint*’ and the terms that are composed of ‘*Concepts*’ and ‘*Associations*’ on the matrix with a MS Excel file. So, it cannot support the inferences that are required to find the mandatory and the optional terms for the architectures. To support the inferences, we create the class ‘*ViewPoint*’ through two transformations as depicted in Figure 5.

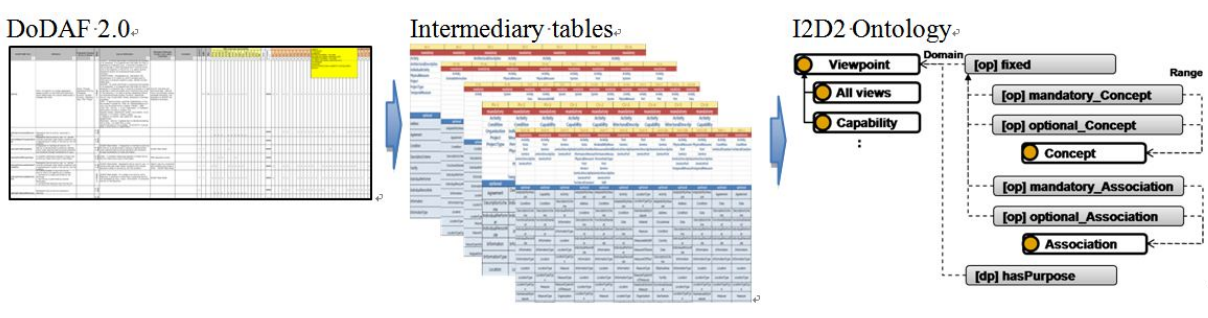

Figure 5: Creation process for the Class ‘*ViewPoint*’ on the I2D2 Ontology

As depicted in Figure 5, the class ‘*Viewpoint*’ is a set of classes that are mapped to eight viewpoints in DoDAF 2.0. Eight viewpoints have a set of instances that are mapped to Views. The relationships between the class ‘*Viewpoint*’ and the class ‘*Concept*’ are established by properties ‘*mandatory_Concept*’ and '*optional_Concept*.' Similarly, two properties '*mandatory_Associaiton*' and '*optional_Associaiton*' are established to specify the relationships between the class '*Viewpoint*' and the class '*Associaiton*.'

4.2 Class '*DataGroup*' and '*TargetViews*'

Class '*DataModel*' is devised to specify the '*Concepts*,' '*Associations*,' and their relationships including hypo-hyper relations and/or associative relations. In Figure 6, left pane is represented to the terms in the DoDAF 2.0 and right pane is the structure of the class '*DataModel*' on the I2D2 Ontology.

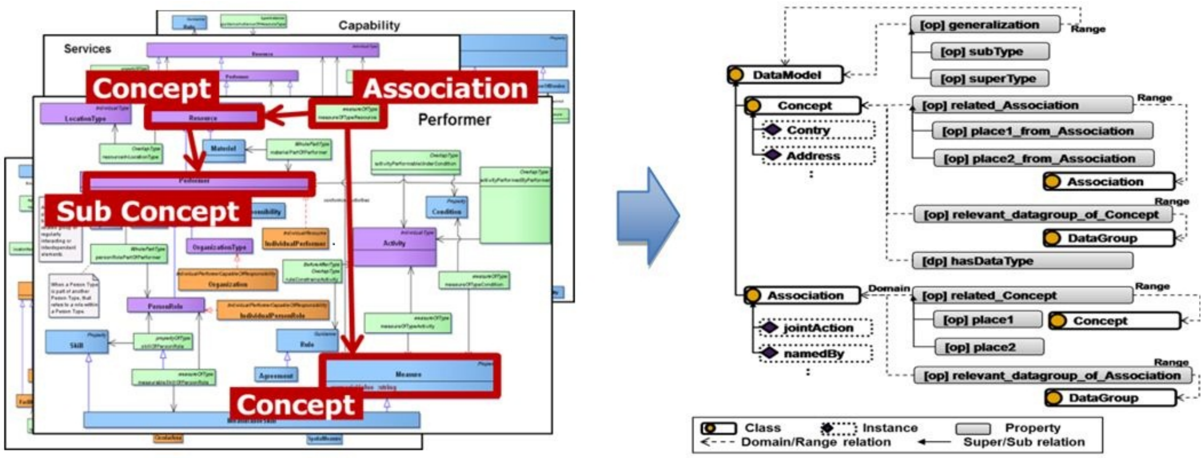

Figure 6: Structure of the Class '*DataModel*' on the I2D2 Ontology

4.3 Class '*DataGroup*' and '*TargetViews*'

It is created to reversely infer the data groups for the '*Concepts*' and the '*Associations*.' Class '*Data-Group*' is comprised of two core classes, named '*PrincipleDataGroup*' and '*SupportingDataGroup*.' As mentioned in Table 1, the former data group has nine elements and the latter data group consists of three elements. '*TargetView*' is a class that can manage the overall information about the data models for the architecture description. The ontological views of the class '*DataGroup*' and the class '*TargetView*' are depicted in Figure 7.

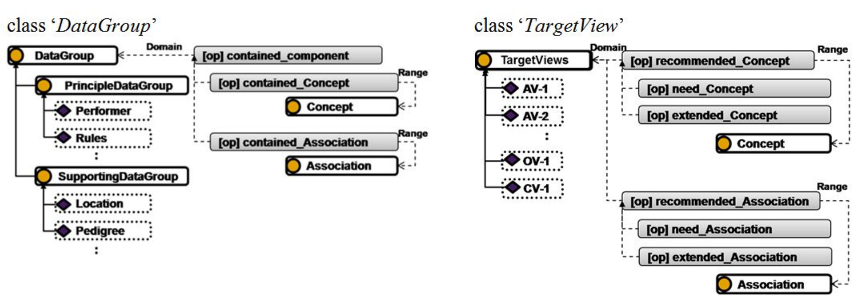

Figure 7: Ontological views of the Class '*DataGroup*' and the Class '*TargetView*'

5 Implementation and Evaluation

To support the whole process of the data modeling for the architecture descriptions, we implement the prototype system, named the I2D2 framework. The I2D2 Ontology as a core element of the framework is developed using OWL (Web Ontology Language) and Protégé 3.4. In addition, we adopt FaCT++ and Jess as the inference engines and Java and Eclipse for GUI design. The structure of the I2D2 Ontology using Protégé 3.4and the interface for the CARM are depicted in Figure 8.

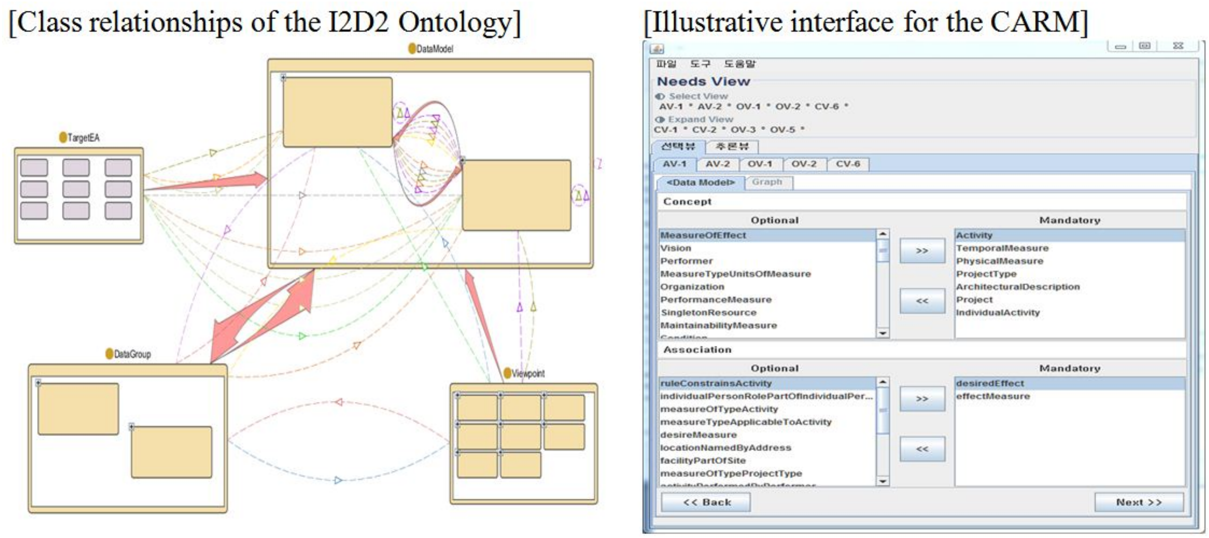

Figure 8: Class relationships of the I2D2 Ontology and Illustrative interface for the CARM

To show the effectiveness of the I2D2 framework, we perform a case study. The target problem of the case study is selected from examples in the MODAF handbook (Version 1.2.003) [16]. In our case, we assume that the system architects determine the Models AV-1, AV-2, StV6, OV1s, and OV2 to satisfy the purpose of the architecture. As an execution result of the I2D2 framework, additional views, named CV-1, CV-2, OV-3, and OV-5 are inferred. Furthermore, the I2D2 framework can search the whole '*Concepts*' and '*Associations*' that are related to the architecture descriptions. The execution results are compared on Table 2.

	ACID Framework		LDM in Matrix	
View set	Recommended Concepts	Recommended Associations	Mandatory Concepts	Mandatory Associations
AV-1	**10**	**9**	7	2
AV-2	0	0	0	0
CV-1	5	**3**	5	0
CV-2	6	**4**	6	0
CV-6	6	**4**	6	0
OV-1	**4**	**6**	1	3
OV-2	1	**1**	1	0
OV-3	5	**1**	5	0
OV-5	**4**	**6**	2	3

Table 2: Comparison of Execution results

We know that if the I2D2 framework is applied to the terms exploring for the architecture descriptions, then it performed better results on augmentation of the terms that are explicitly and/or implicitly related to the views. For example, DM2 specifies seven mandatory concepts and two mandatory associations for the AV-1. For our system, ten mandatory concepts and nine mandatory associations are recommended via applying the association rules. Furthermore, we perform the additional experiments to prove the superiority of our framework. To do so, we generate the experimental set that is composed of the arbitrary number of views and perform the experiments. The experimental results are summarized in Table 3.

	ACID Framework		LDM in Matrix	
View set	Recommended Concepts	Recommended Associations	Mandatory Concepts	Mandatory Associations
5	**25**	**16**	17	6
10	**36**	**28**	23	10
15	**43**	**32**	29	13
20	**62**	**41**	32	15

Table 3: Comparison of Execution results

Similar to the results of the case study, it demonstrates better results on augmentation of the terms that are explicitly and/or implicitly related to the views.

6 Implementation and Evaluation

It goes without saying that security is one of the most important considerations in military domain. Nevertheless, many enterprise architecture frameworks including the DoDAF 2.0 do not adequately address security and furthermore, do not specify the tools and methodologies to develop the security-aware architecture description [6, 18]. To address security requirements, the DoDAF 2.0 specifies the security elements through the mapping the Models to the DM2 Concept including Concepts, Associations, and Attributes [4]. The relations are provided with tabular form. For instance, we know that a DM2 concept '*Classification*' is security attributes for all the Models. In addition, the DoDAF 2.0 assigns the security characteristics and protective measures to elements of the DoDAF viewpoints. At this time, the security characteristics that are must be obeyed are composed of four elements like Environment, Asset Value, Criticality, and Personnel Clearance, and the protective measures comprised of Physical, Procedural, Communication Security (COMSEC), Transient Electromagnetic Pulse Emanation Standard (TEMPEST), and Information Security (INFOSEC). The security requirements are not specified on the viewpoints in the DoDAF 2.0 but shown on models using annotations and call–outs [4]. For example, the concept '*Function*' related to '*System Viewpoint (SV)*' must take into consideration the '*Security Marking*' and the '*Criticality*' as the security characteristics. Furthermore, it has two kinds of protective measures like INFOSEC and Procedural. Even though security is critically important consideration in the DoD's core processes, the DoDAF 2.0 does not have not only a separate Viewpoint for security but also explicit Models for the viewpoints. Furthermore, the conventional methods like annotations and/or call–outs are inadequate to ensure the security of the architecture descriptions. So, we strongly argue that the DoDAF 2.0 has to have not an additional viewpoint with related to security additional Models the can handle the security issues from the viewpoints' perspective. We are now studying what kinds of Models are added on the Viewpoint and what will be included in the Models.

7 Implementation and Evaluation

We propose and implement the I2D2 framework and the I2D2 Ontology. The framework includes the data model ontology and three parts: ONT-DAF, Concept and Association Reasoning Module, and Sub-Concepts Identification Module. The data model ontology, named the I2D2 Ontology is a core element of the framework. It is composed of four classes and 22 properties that represent the relationships among the classes. Also, we demonstrate the performance of our framework and ontology via several case studies. In the case studies, it was shown that our framework can be useful for describing the architectures in terms of the '*Concepts*' and the '*Associations.*' Contributions of this study are summarized as follows. First, we applied the ontology and rule-based inference embedded onto the data model development for the DoDAF 2.0. Second, the I2D2 framework contributes not only to identify precisely and totally the relationships between terms in the DODAF 2.0 but also to reduce the development burden on the data model. This research can be extended to several directions. We need to implement a solution that can support the overall processes for the architecture development. Second, additional research is needed to enhance the security issues. Finally, we will perform the evaluation on the I2D2 framework to prove its adequacy and efficiency.

Acknowledgment

This research was partially supported by the IT R&D program of MKE/KEIT [No. 10041788, Development of Smart Home Service based on Advanced Context-Awareness] and partially supported by the MSIP (Ministry of Science, ICT and Future Planning), Korea, under the "IT Consilience Creative Program" (NIPA-2014-H0201-14-1001) supervised by the NIPA(National IT Industry Promotion Agency)

References

[1] D. Allemang, R. Hodgson, and I. Polikoff. Fea reference model ontologies: Fea-rmo version 1.1. 2005.

[2] Z. Chen and R. Pooley. Rediscovering zachman framework using ontology from a requirement engineering perspective. In *Proc. of the 33rd Annual IEEE International Conference on Computer Software and Applications (COMPSAC'09), Seattle, WA, USA*, volume 2, pages 3–8. IEEE, July 2009.

[3] G. Dalton, J. Colombi, and B. Mills. Modeling security architectures for the enterprise. In *Proc. of the 11th International Command and Control Research and Technology Symposium (ICCRTS'06), Cambrage, UK*, June 2006.

[4] Department of Defense. Department of defense architecture framework 2.0, 2009.

[5] J. DiDuro, R. Crosslin, D. Dennie, and P. Jung. A practical approach to integrating information security into federal enterprise architecture (no.lmi-ir229t1). *Logistics Management McLean VA*, 2002.

[6] L. Ertaul and J. Hao. Enterprise security planning with department of defense architecture framework (DODAF). In *Proc. of The 2011 International Conference on Security and Management (SAM'11), LasVegas, Nevada, USA*, July 2011.

[7] H. A. H. Handley. Incorporating the nato human view in the dodaf 2.0 meta model. *Systems Engineering*, 15(1):108–117, July 2011.

[8] Ideas Group. DoDAF DM2 LDM diagramming tool, 2011.

[9] V. Jain and M. Singh. Ontology development and query retrieval using protégé tool. *International Journal of Intelligent Systems and Applications (IJISA)*, 5(9):67, 2013.

[10] S. Jalaliniya and F. Fakhredin. Enterprise architecture & security architecture development. 23(3):163–207, 2011.

[11] D. Kang, J. Lee, S. Choi, and K. Kim. An ontology-based enterprise architecture. *Expert Systems with Applications*, 37(2):1456–1464, 2010.

[12] A. Kärkkäinen. *A cyber security architecture for military networks using a cognitive network approach*. PhD thesis, National Defence University, 2013.

[13] Y. M. Kwon, M. Sohn, and H. J. Lee. The design and implementation of ontology for architecture framework (ont-daf) in military domain. *International Journal of Control & Automation*, 5(2), 2012.

[14] L. Li, Y. Dou, B. Ge, and K. Yang. Executable system-or-systems architecting based on DoDAF Meta-model. In *Proc. of the 7th International Conference on System of Systems Engineering (SoSE'12), Genoa, Italy*, pages 362–367. IEEE, July 2012.

[15] Marina Arseniev. Enterprise architecture implementation: Practical steps using open source tools, 2009.

[16] Ministry of Defence. MoD architecture framework v1.2.004, 2010.

[17] Ministry of Defence. MODAF M3 version 1.2.004, 2013.

[18] W. R, Conkling, and J. A. Hamilton. Suggested improvements to the dodaf for modeling architectural security. In *Proc. of the 2009 Spring Simulation Multiconference (SpringSim'09), San Diego, CA, USA*, volume Article No. 53, March 2009.

[19] T.Kilpeläinen and M.Nurminen. Applying genre-based ontologies to enterprise architecture. December 2007.

[20] X. xue Zhang, X. shan Luo, and A. min Luo. Method of architecture executable evaluation based on DM2. In *Proc. of the 3rd International Conference on System Science, Engineering Design and Manufacturing Informatization (ICSEM'12), Chengdu, China*, volume 1, pages 213–217. IEEE, October 2012.

Author Biography

Mye M. Sohn is an associate professor in the Department of Systems Management Engineering at Sungkyunkwan University and the Director of the Centre for Woman in Science, Engineering and Technology in Gyeonggi. She received her MS and Ph. D. from the Korea Advanced Institute of Science and Technology (KAIST). Sohn's research has been focused on the Internet of Things, Linked Open Data, semantic web, ontology, context-aware computing, and enterprise architecture. She got the best paper awards in KIIS ('03) and KMES ('11). She has published several papers in Communications of the ACM, Information Sciences, An International Journal of Mathematical and Computer Modelling, and so on.

Saerom Kang is a graduate student in the Department of Industrial Engineering at Sungkyunkwan University. He received his BA Degree from Namseoul University. Her current research issues focuses on ontology, semantic web, Architecture Framework, Semantic Web, Ontology, and Enterprise Architecture.

Hyun Jung Lee is a senior researcher of Yonsei Institute of Convergence Technology at Yonsei University. She received her Ph.D. from Korea Advanced Institute of Science and technology (KAIST). Her main interest is decision support systems, Semantic Web, Ontology, Recommendation Systems, and Knowledge Management Systems. She has published several papers in Decision Support Systems, Journal of Information Technology, and so on.