

The Ontology-Based Methodology Phases To Develop Multi-Agent System (OmMAS)

Arda Yunianta

Faculty of Computing and Information Technology,
King Abdulaziz University, Rabigh, Saudi Arabia.
Faculty of Computer Science and Information Technology,
Mulawarman University, Indonesia.
ayunianta@kau.edu.sa

Aina Musdholifah

Department of Computer Science and Electronics,
Faculty of Mathematics and Natural Science,
Gadjah Mada University, Indonesia.
aina_m@ugm.ac.id

Nataniel Dengen, Haviluddin

Faculty of Computer Science and Information Technology,
Mulawarman University, Indonesia.
ndengen@gmail.com, haviluddin@gmail.com

Omar Obarukab, Norazah Yusof

Faculty of Computing and Information Technology,
King Abdulaziz University, Rabigh, Saudi Arabia.
obarukab@gmail.com, nyusof@kau.edu.sa

Herlina Jayadiyanti

Faculty of Industrial Engineering, Informatics Department,
UPN Veteran Yogyakarta, Indonesia.
herlinajayadianti@gmail.com

Mohd Shahizan Othman

Faculty of Computing,
University Teknologi Malaysia, Malaysia.
shahizan@utm.my

Abstract—Semantic aspect on methodology phase is a significant issue to develop multi-agent system in the current days. There are a lot of methodologies to develop multi-agent system, but the current problem is how to choose the best methodology phase to develop current multi-agent system. The development of multi-agent system currently is to be more complex and difficult. Many aspects that contains on multi-agent system, the one of the famous issue now is about semantic aspect on multi-agent system. The old methodology phases are not suitable to develop current multi-agent system. Nowadays, many researchers start to improve and customize the obsolete methodology to adjust with the current needed. There are two research steps contains in this paper, the first step is to review and criticize previous methodologies especially about MOMA (Methodology for Developing Ontology-Based Multi-Agent System) was introduced in 2013. The second step is the main contribution of this paper is to improve previous methodology phases with the new methodology phases named OmMas (The Ontology-Based Methodology phases to Develop Multi-Agent System), and using semantic aspect as the main focus of this methodology. The result of this research is improved ontology-based methodology phases as a representation of semantic aspect on the ontology development process.

Keywords—methodology; multi-agent system; ontology knowledge; semantic approach

I. INTRODUCTION

A multi-agent system is among the promising solution to solve complex problems in software engineering [1]. The

objective of multi-agent systems is to build distributed, intelligent, and robust applications [2]. However, there are many issues faced by the researchers to develop the multi-agent system, such as the issues of structured and unstructured data; heterogeneity of the system and information; interoperability between systems and many more [3-7]. Currently, one of the prevalent issue in multi-agent system is the semantic aspect [4].

Even though there are many updates regarding the new methodology techniques to handle semantic aspect on multi-agent system, discussions on the ontology-based in the methodology phase is still limited [4, 8]. One critical problem that makes the development of multi-agent system becomes unsuccessful is because of not using a good development methodology [2, 5, 9]. Researchers are focusing on the methodology design to accommodate the need of semantic aspects in multi-agent system development. This is due to the fact that the existing methodologies are obsolete and need to be improved with the current needs.

The aim of this paper is to critically analyze the existing development methodology on multi agent system, named Methodology for Developing Ontology-Based Multi-Agent Systems (MOMA) [4]. After identifying the limitations of MOMA, this research proposes an improved development methodology named Ontology-Based Methodology Phases to Develop Multi-Agent System (OmMAS).

This paper is divided into several sections. The first is the introduction and the problem statement. The second section is to analyze and identify the weaknesses of MOMA. The third section is to define the suitable Ontology-Based Methodology Phases to Develop Multi-Agent System (OmMAS). And finally, the last section is to conclude OmMAS as a potential development methodology.

II. EXISTING ONTOLOGY-BASED METHODOLOGY (MOMA)

Nowadays there are many methodologies that have been proposed based on a variety of concepts, notations, and techniques [4, 5, 8]. Among them are the ontology development methodologies, such as MOMA [4], Methontology [10], Kactus [11], On-To-Knowledge [12], Enterprise [13, 14], Cyc [15], Sensus [16], Tove [17], NeON [18], Diligent [19], (KA)2 [20], and CO4 [21, 22].

Every methodology has a specific purpose and has different phases to build the ontology knowledge. One purpose for building ontology is to allow reuse of domain ontology. Second, is to share among the people or the software agents about the common understanding on the structure of information. Third, is to separate the domain knowledge from the operational knowledge. Another common reason to construct an ontology is to make the domain assumption explicit, so that it is easier to update and to validate the assumptions.

Unfortunately, not all methodologies are suitable to develop ontology knowledge in the multi agent system. To develop ontology knowledge, it should be well defined, designed and developed using the right phases to illustrate the state of reality or the domain of discourse. Moreover, developing ontology knowledge is not an easy process and need more time, resources and deeper analysis [22-24]. This paper focuses on the methodology for developing Ontology-Based Multi-Agent System (MOMA) [4] as the current ontology-based methodology in a multi-agent system.

This paper investigates in details the ontology development phase of the MOMA.

A. Methodology for Developing Ontology-Based Multi-Agent Systems (MOMA)

MOMA is compelled by semantic aspects using ontology-based. To develop a multi-agent system in the MOMA methodology, there are two main phases of the MOMA [4]. The first phase is the ontology development phase. The second phase is the agent development phase and one extra phase is the agent application that is outside of the MOMA. There is no detail explanation of the agent development phase in the previous research [4], how to use and involve the result from ontology development phase that will be used in the agent development phase. Detail of the MOMA phases can be seen in figure 1.

This research focuses only on the ontology development phase in the MOMA. The purpose of this ontology development phase is to develop ontology knowledge that will be used in the agent development phase. There are four main

phases in the ontology development phase that can be seen on figure 2.

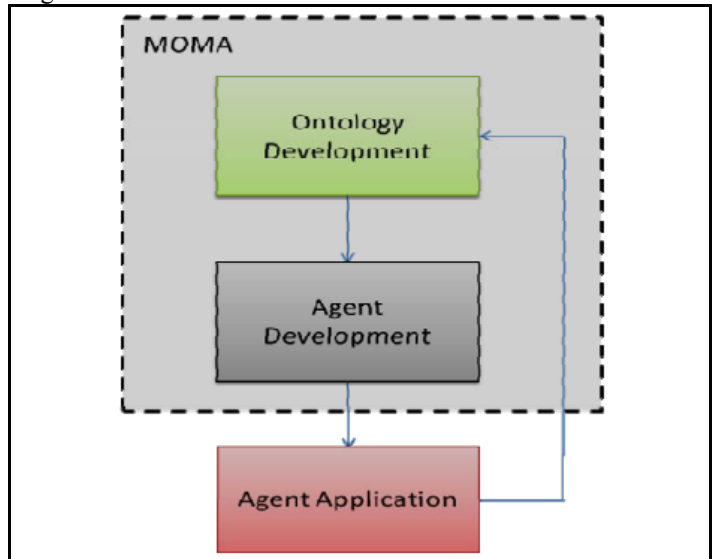


Fig. 1. Main Phases of MOMA based on Ying, W et al [4].

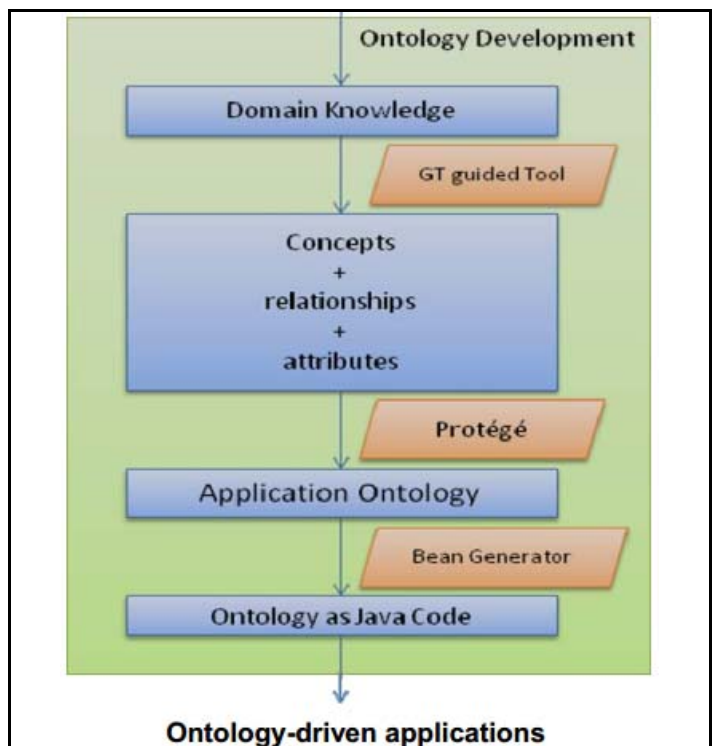


Fig. 2. Ontology Development Phases on MOMA based on Ying, W et al [4].

Figure 2 illustrates the detail breakdown process of the ontology development phase in the MOMA methodology, as it conveys from domain knowledge to ontology to java code [4]. There are four main phases in the ontology development phase in the MOMA methodology. Firstly, various sources of knowledge are gathered by the domain experts. Secondly, is the phase to create concepts, relationships, and attributes using

a tool based on Grounded Theory (GT). Third, is modeling the application ontology through the Protégé ontology development tool. The final phase is the conversion of the ontology into java code using the Bean Generator. The result from this flow is the code generation in which it can be reused in an ontology-driven application.

In general, the steps in the ontological development process are run without involving iteration.

Determine scope → consider reuse → enumerate terms → define classes → define properties → define constraints → create instances.

Even though the steps in the ontological development process are run without involving iteration, but in reality the process involved iteration.

Determine scope → Consider reuse → Enumerate terms → Consider reuse → Define classes → Enumerate terms → Define classes → Define properties → Define classes → Define properties → Define constraints → Create instances → Define classes → Create instances → Consider reuse → Define properties → Define constraints → Create instances.

B. Critically analysis on MOMA

One main advantage of MOMA is that the ontology development phases is simple. There are only four main steps, which are: identify domain knowledge; create concepts, relationships and attributes using GT guided tool; develop ontology using protégé tool; and generate code from ontology to java code. By using the tools driven by the ontology, MOMA can be applied in the multi-agent system (MAS) development. This approach can speed up the development of the ontology-based application.

On the other hand, there are several constraints of MOMA methodology that have been discovered. It is revealed that MOMA only partially successful in enabling the development of a complete application development by the domain experts. In other words, MOMA still requires the agent developer and the software engineer to get involve [4].

Another limitation of MOMA is that it is tested and evaluated specifically in the financial services. This means that MOMA is highly successful to be used in the financial services only, but not in other domain.

Moreover, Ying W. et al mentioned that the ontology development phases on MOMA methodology are not structured and generalized in order to be reused in other domains [4].

Another drawback for the user who builds an ontology with MOMA methodology is the inconsistent ontology. An inconsistent ontology happens when no classes in ontology can have instances and no meaningful knowledge can be drawn from the ontology. As a result, it becomes impossible to

interpret the axioms in the ontology. The ontology can become inconsistent during the editing process, where some axioms are added. To overcome inconsistencies, several numbers of common phases need to be iterated. Unfortunately, there is no iteration occurs in the ontology development of MOMA [4]. Currently, MOMA consists of four phases with no reiteration.

Domain Knowledge → concepts, relationships, attributes → application ontology → ontology as java code.

As a result, when inconsistent ontology occurs, it is very difficult to iterate back to the concept. In order to overcome the ontology inconsistency, there's a need to propose an ontology development process that involved iteration.

III. SUITABLE ONTOLOGY-BASED METHODOLOGY PHASES FOR MUTI-AGENT SYSTEM (OMMAS)

From comprehensive literature review and conduct the critical analysis, this paper proposes custom phases of ontology development methodology. The methodology phases are to develop an ontology and come out with nine essential phases as shown in Figure 3. Six of the phases are the general phases which are obtained from the ontology development methodology. Meanwhile, three phases are added in the methodology that is considered as the essential contribution to this work.

The first phase of this methodology is to define the purpose of ontology development. The domain ontology is important to be acknowledged in order to identify and limit the scope of the ontology. With the identified scope, ontology developer is able to specify the requirements that the ontology should fulfill.

The second phase is to identify the resources from the multi-agent system that relates with information that contains specifications of the system. Based on the requirements specified in the first phase, ontology developers should develop criteria and measures for identifying related resources; they should then identify possible resources related to the domain and make them available.

The third phase is to Reengineer and Reuse the Resources phase which involves the selecting of important information to be used in the multi-agent system. This phase relates to the purpose of ontology development. However, such resources are not entirely useful as they are. So, they should be selected and modified or re-engineered to serve the intended purpose.

The fourth phase is to Conceptualize all the terms and relationships into meaningful models at the knowledge level. Terms are possible information that generated from every multi-agent system. Terms are represented as classes and relationships are presented as object properties on ontology perspective. This should be done by identifying key concepts and relationships in the domain of interest, to produce precise and unambiguous text definitions for such concepts and relationships and to identify the terms to refer to such concepts and relationships.

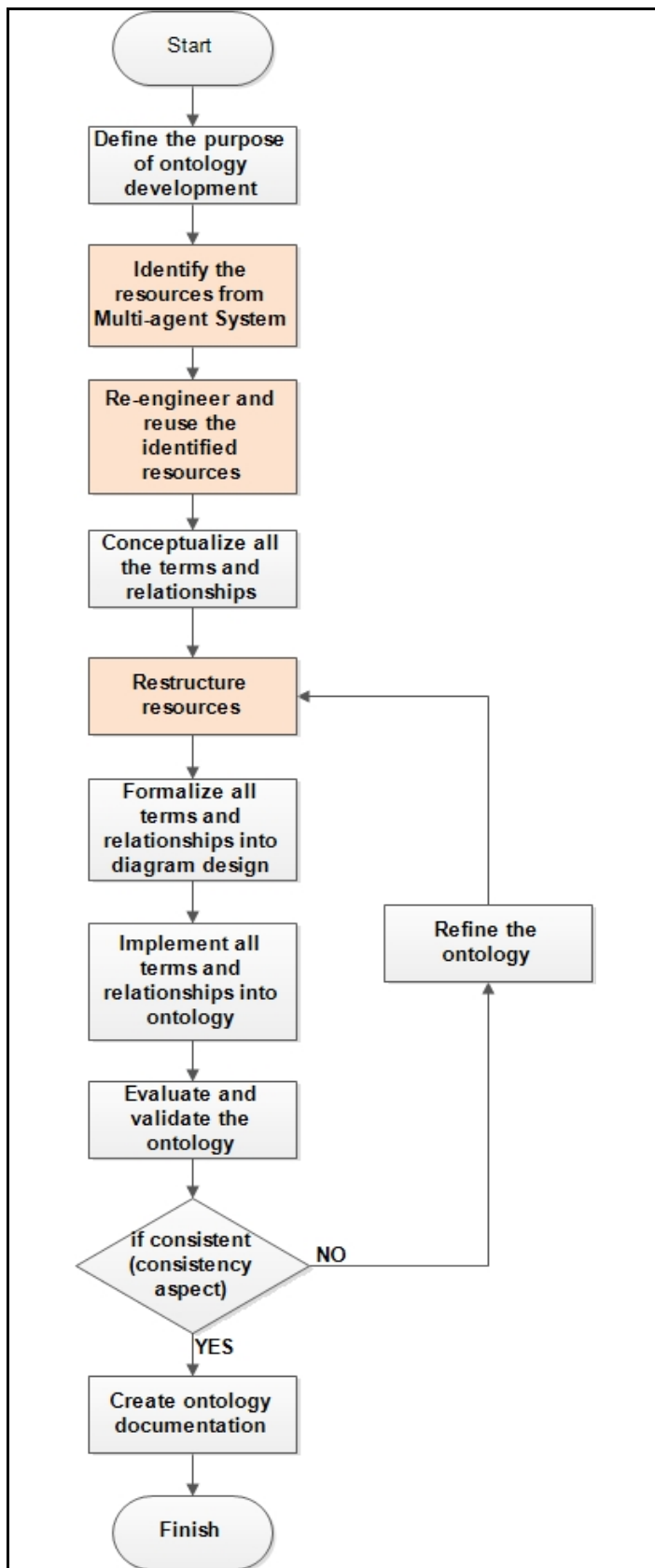


Fig. 3. Ontology-Based Methodology Phases for Multi-Agent System (OmMAS)

During the conceptualization phase, the conceptual or domain ontology should be built [25]. The output of this phase should be a document containing the conceptual model and all the terms and relationships that should be in the ontology, with a text definition of each term and relationships, constraints among these terms, relationships, and properties of the terms and relationships.

The fifth phase is to restructure resources, this phase is the activity of correcting and reorganizing the knowledge contained in an initial conceptual model, and detecting missing knowledge [26]. After the conceptualization activity, from the selected and re-engineered resources, ontology developers should perform the restructuring activity to modify ontology after evaluating it technically. Determine which Terms to be classes in ontology and which Terms to be sub classes in ontology perspective. In the restructure resources, is to create a new attribute in ontology named data property. Data property also important in ontology is because of data property gives an extra attribute on each instance in the ontology. As a more information, instances are included into ontology from semantic data integration process. The instances are all of related data and information in every source to be integrated into the ontology as a final purpose of this research.

The sixth phase is to Formalize all terms and relationships, this phase is the conceptual model to transform all terms and relationships into a semi-computable model. Semi-computable model is using diagram-drawing tools to draw the ontology model before the ontology develops in ontology development tools. This stage aim is to start the evaluation process to see and analyze whether the ontology is in conformity with the objectives or not. The completed description of the domain in the previous step is written in a more formal form, although not yet its final forms. Concepts are usually defined through axioms that restrict the possible interpretations of the meanings of those concepts.

The seventh phase is to implement all terms and relationships into the ontology. Choosing the appropriate ontology representation language is important to precisely and unambiguously represent the model. Furthermore, choosing the best tools is indispensable to facilitate building the learning ontology. In this research, protégé 4.3 is chosen as a tool to develop the ontology knowledge. Protégé 4.3 is one of recommendation tools to develop an ontology knowledge, it is because of protégé is a free tool and have a reasoner as a one of the methods to validate the ontology development.

The eight phases are Evaluate and validate the ontology, this phase is to get the verification of the ontology weather it has consistency acceptance or still has any inconsistency on that ontology. Evaluation and validation phase is the continuous and iterative activity of carrying out a technical judgment of the ontologies, with respect to the requirement specification document during each phase and between phases. It is also worthwhile considering Gruber's (1995) design principle during the development process. The final evaluation is to develop a prototype in a real world setting and evaluate the result in relation to users' requirements [27].

The tenth phase is Refine the ontology, this phase is the iterative process to improve the ontology to get the better ontology result. This phase is to fulfill the ontology requirement and the purpose of the ontology development. Refinement phase can be done when the evaluation and validation of the ontology successfully or get some error. Although the evaluation and validation phase is successful sometimes ontology knowledge still need to do refinement phase to improve the ontology knowledge and get the better result.

The final step is to create ontology documentation that explains in detail every phase on ontology development process. Each completed phase should be clearly and exhaustively documented to facilitate maintenance, use, and reuse. Since this chapter is explaining the phases, then the ontology documentation creation is fulfilled.

To overcome the inconsistency ontology, this paper offers a methodology of Ontology-Based Methodology Phases For Multi-Agent System (OmMAS) that consists of an iterative process.

Ontology development → Purpose → Identify the resources → Re-engineer and reuse the resources → Conceptualize terms and relationships → Restructure resources → Formalize and Implement terms and relationships → Evaluate and Vaidate → (Inconsistency) → Refine the ontology → Restructure resources → Formalize and Implement terms and relationships → Evaluate and Vaidate → Consistency

IV. CONCLUSION

There are a lot of methodology phases to develop the multi-agent system. This research is focused on ontology-based methodology phases to develop the multi-agent system. We try to critically analyze MOMA as the latest ontology-based methodology phases for the multi-agent system. We found that MOMA has several advantages and disadvantages, and from this research we try to solve weaknesses problems on MOMA. Two main problems that solved in this research are about MOMA methodology is not structured and generalized to be reused in other domains; and too simple and there is no iterative activity to evaluate and refine the ontology.

This research developed Ontology-Based Methodology Phases for Muti-Agent System (OmMAS) that contains nine phases including three additional phases as the main contribution to this research. OmMAS phases are more structured and have an iterative activity to evaluate and refine the ontology.

In the next extended paper, we will try to go detail into the development process of OmMAS and implement the OmMAS to develop an ontology-based multi-agent system on learning domain.

ACKNOWLEDGMENT

This work is supported by King Abdulaziz University. The authors would like to thank the Deanship of Scientific Research Management (DSR) King Abdulaziz University for the support and incentive extended in making this study a success.

REFERENCES

- [1] J. Gomez-Sanz and J. Pavon, "Methodologies for Developing Multi-Agent Systems," *Journal of Universal Computer Science*, vol. 10, pp. 359-374, 2004.
- [2] M. F. Wood and S. A. DeLoach, "An Overview of the Multiagent Systems Engineering Methodology," in *Agent-Oriented Software Engineering: First International Workshop, AOSE 2000 Limerick, Ireland, June 10, 2000 Revised Papers*, P. Ciancarini and M. J. Wooldridge, Eds., ed Berlin, Heidelberg: Springer Berlin Heidelberg, 2001, pp. 207-221.
- [3] c. K. Pandey and R. Pandey, "Role of multi agent system methodology in system design," in *Computing for Sustainable Global Development (INDIACom), 2015 2nd International Conference on*, 2015, pp. 438-441.
- [4] W. Ying, P. Ray, and L. Lewis, "A Methodology for Creating Ontology-Based Multi-agent Systems with an Experiment in Financial Application Development," in *System Sciences (HICSS), 2013 46th Hawaii International Conference on*, 2013, pp. 3397-3406.
- [5] V. M. B. Werneck, R. M. E. M. Costa, and L. M. Cysneiros, "Modelling MultiAgent System using Different Methodologies, Multi-Agent Systems - Modeling, Interactions, Simulations and Case Studies," D. F. Alkhateeb, Ed., ed: InTech, 2011, pp. 77-96.
- [6] Q.-N. N. Tran and G. Low, "MOBMAS: A methodology for ontology-based multi-agent systems development," *Information and Software Technology*, vol. 50, pp. 697-722, 6// 2008.
- [7] R. H. Bordini, M. Dastani, and M. Winikoff, "Current Issues in Multi-Agent Systems Development," in *Engineering Societies in the Agents World VII: 7th International Workshop, ESAW 2006 Dublin, Ireland, September 6-8, 2006 Revised Selected and Invited Papers*, G. M. P. O'Hare, A. Ricci, M. J. O'Grady, and O. Dikenelli, Eds., ed Berlin, Heidelberg: Springer Berlin Heidelberg, 2007, pp. 38-61.
- [8] R. Sharman, R. Kishore, and R. Ramesh, "Computational Ontologies and Information Systems II: Formal Specification," *Communications of the Association for Information Systems*, vol. 14, 2004.
- [9] K. P. Sycara. (1998) Multiagent Systems. *AI Magazine*. 79-92.
- [10] M. Fernandez, A. Gomez-Perez, and N. Juristo, "Methontology: From ontological art towards ontological engineering," in *the AAAI 1997 Spring Symposium Series*, Menlo Park, CA, 1997.
- [11] G. Schreiber, B. Wielinga, and W. Jansweijer, "The KACTUS view on the 'O'word," presented at the IJCAI workshop on basic ontological issues in knowledge sharing, 1995.
- [12] S. Staab, R. Studer, H.-P. Schnurr, and Y. Sure, "Knowledge Processes and Ontologies," *IEEE Intelligent Systems*, vol. 16, pp. 26-34, 2001.
- [13] M. Uschold and M. King, "Towards a methodology for building ontologies," in *Workshop on Basic Ontological Issues in Knowledge Sharing, held in conduction with IJCAI-95*, New York, NY, 1995.
- [14] M. Uschold, "Building ontologies: Towards a unified methodology," in *16th Annual Conference of the British Computer Society Specialist Group on Expert Systems*, London, UK., 1996.
- [15] K. Knight and S. K. Luk, "Building a large-scale knowledge base for machine translation," presented at the Proceedings of the twelfth national conference on Artificial intelligence (vol. 1), Seattle, Washington, USA, 1994.
- [16] B. Swartout, R. Patil, K. Knight, and T. Russ, "Towards distributed use of large-scale ontologies," in *10th. Knowledge Acquisition for Knowledge-Based Systems Workshop*, Banff, Canada, 1997.
- [17] M. Gruninger and M. S. Fox, "Methodology for the design and evaluation of ontologies," in *Workshop on Basic Ontological Issues in Knowledge Sharing: International Joint Conference on Artificial Intelligence (IJCAI95)*, New York, NY, 1995.
- [18] M. C. Suárez-Figueroa, A. Gómez-Pérez, and M. Fernández-López, "The NeOn Methodology for Ontology Engineering," in *Ontology Engineering in a Networked World*, M. C. Suárez-Figueroa, A. Gómez-

- Pérez, E. Motta, and A. Gangemi, Eds., ed Berlin, Heidelberg: Springer Berlin Heidelberg, 2012, pp. 9-34.
- [19] H. S. Pinto and J. P. Martins, "Ontologies: How can They be Built?," *Knowledge and Information Systems*, vol. 6, pp. 441-464, 2004/07/01 2004.
- [20] V. Richard Benjamins, D. Fensel, S. Decker, and A. G. PÉRez, "(KA)2: building ontologies for the Internet: a mid-term report," *International Journal of Human-Computer Studies*, vol. 51, pp. 687-712, 9// 1999.
- [21] J. Euzenat, "Building Consensual Knowledge Bases: Context and Architecture," in *KB&KS '95 Conference*, 1995, pp. 143--155.
- [22] K. B. A. Badr, A. B. A. Badr, and M. N. Ahmad, "Phases in Ontology Building Methodologies: A Recent Review," in *Ontology-Based Applications for Enterprise Systems and Knowledge Management*, ed: IGI Global, 2013, pp. 100-123.
- [23] W. Jaziri and F. Gargouri, "Ontology Theory, Management and Design: An Overview and Future Directions," in *Ontology Theory, Management and Design: Advanced Tools and Models*, ed: IGI Global, 2010, pp. 27-77.
- [24] N. S. Abdullah, S. Sadiq, and M. Indulska, "A Study of Ontology Construction: The Case of a Compliance Management Ontology," in *Ontology-Based Applications for Enterprise Systems and Knowledge Management*, ed: IGI Global, 2013, pp. 276-291.
- [25] J. V. Fonou-Dombeu and M. Huisman, "Combining ontology development methodologies and semantic web platforms for e-government domain ontology development," *IJWEST Journal*, vol. 2, pp. 12-25, 2011.
- [26] A. Gómez-Pérez and M. Rojas-Amaya, "Ontological Reengineering for Reuse," in *Knowledge Acquisition, Modeling and Management*. vol. 1621, D. Fensel and R. Studer, Eds., ed: Springer Berlin Heidelberg, 1999, pp. 139-156.
- [27] T. R. Gruber, "Toward principles for the design of ontologies used for knowledge sharing," *Int. J. Hum.-Comput. Stud.*, vol. 43, pp. 907-928, 1995.