ONTOLOGY-BASED SEMANTIC HETEROGENEOUS DATA INTEGRATION FRAMEWORK FOR LEARNING ENVIRONMENT

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This thesis is dedicated to…

My Wife, who always give me full of support and spirit without failed.

My Father, My Mother, my brothers that who always supporting me in my PhD

journey.

To my supervisor, Associate Professor Dr. Mohd Shahizan Othman, Co sv, Associate

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ABSTRACT

Nowadays, e-learning has become important supporting tools for effective learning. Therefore, integrating a good learning environment in e-learning can improve learning process. Good learning environment can provide new knowledge. Currently, there are many distributed systems and applications on learning environment that involve heterogeneity data in data level implementation. Different learning applications have different system designs and data representations. The main problem on learning environment is that every individual learning application has limited capability to share data and information. Moreover, existing data integration approaches still have weaknesses and there has been less research done on the learning environment of data integration. This research proposes a semantic data integration framework is to handle data heterogeneity on learning environment that integrates various learning information to produce new learning knowledge. This research focuses on semantic data integration using an ontology approach to handle semantic relationship between data sources. The research methodology consists of three main stages. The first stage is semantic data mapping to standardize the heterogeneity data representation from numerous data sources into a standard file format. The second stage is to design and develop the ontology knowledge to create semantic relationship between different data sources. The third stage is to combine the ontology knowledge with the semantic data mapping file to produce semantic data integration. Ontology validation process on this framework uses Resource Description Framework (RDF) validator by World Wide Web Consortium (W3C) standardization and Factplusplus (FaCT++) reasoning in order to check the consistency of classes, instances and properties. Moreover, to validate the framework, this research employs the quality criteria and the metric, based on the Quality Framework for Data Integration approach. The quality criteria focus on the completeness and consistency of the data sources, while the metric produces the quality factor to determine the degree of acceptance. This framework is then verified by adding three different learning systems with heterogeneity in data level implementation which are the Moodle e-learning system, the Question Bank system and the Student Grading system. This framework successfully integrates the different data sources with heterogeneity data representation using quality factor formulas and the result shows that this framework is capable to produce new learning knowledge that involves complex learning information.

ABSTRAK

Kini, e-pembelajaran menjadi alat sokongan penting bagi pembelajaran efektif. Oleh itu, mengintegrasikan sebuah persekitaran pembelajaran yang baik dalam e-pembelajaran dapat meningkatkan mutu proses pembelajaran. Persekitaran pembelajaran yang baik dapat mewujudkan pengetahuan baru. Kini, terdapat banyak sistem dan aplikasi teragih dalam persekitaran pembelajaran yang melibatkan kepelbagaian data pada peringkat perlaksanaan data. Aplikasi pembelajaran yang berbeza mempunyai sistem reka bentuk dan perwakilan data yang berbeza. Masalah utama persekitaran pembelajaran adalah setiap aplikasi pembelajaran individu mempunyai keupayaan yang terhad untuk berkongsi data dan maklumat. Selain itu, pendekatan integrasi data sedia ada masih mempunyai kelemahan dan kurang penyelidikan dilakukan ke atas persekitaran pembelajaran bagi integrasi data. Kajian ini mencadangkan rangka kerja integrasi data semantik untuk mengendalikan kepelbagaian data dalam persekitaran pembelajaran yang dapat mengintegrasikan pelbagai maklumat pembelajaran untuk menghasilkan pengetahuan pembelajaran yang baharu. Kajian ini tertumpu ke atas integrasi data semantik menggunakan pendekatan ontologi untuk mengendalikan hubungan semantik antara sumber data. Metodologi kajian terdiri daripada tiga peringkat utama. Peringkat pertama adalah pemetaan data semantik untuk menyelaraskan perwakilan kepelbagaian data dari pelbagai sumber data ke dalam format fail standard. Peringkat kedua adalah untuk mereka bentuk dan membangunkan pengetahuan ontologi untuk mencipta hubungan semantik antara pelbagai sumber data. Peringkat ketiga adalah untuk menggabungkan pengetahuan ontologi dengan fail pemetaan data semantik untuk menghasilkan integrasi data semantik. Proses pengesahan ontologi pada kajian ini menggunakan pengesah Rangka Kerja Perihal Sumber (RDF) oleh piawaian Konsortium Jaringan Sejagat (W3C) dan pertimbangan Factplusplus (FaCT++) untuk memeriksa konsistensi kelas, keadaan dan sifat-sifat pada ontologi. Tambahan pula, untuk mengesahkan rangka kerja, kajian ini menggunakan kriteria kualiti dan metrik, berdasarkan pendekatan Kualiti Rangka Kerja untuk Integrasi Data. Fokus kualiti kriteria ialah ke atas kelengkapan dan konsistensi sumber data, manakala metrik menghasilkan faktor kualiti untuk mengenalpasti darjah penerimaan. Rangka kerja ini kemudian disahkan dengan menambah tiga sistem pembelajaran berlainan dengan kepelbagaian data dalam perlaksanaan peringkat data yang mana adalah; sistem e-pembelajaran Moodle, sistem Bank Soalan dan sistem Penggredan Pelajar. Rangka kerja ini berjaya mengintegrasikan pelbagai sumber data dengan perwakilan kepelbagaian data menggunakan pendekatan ontologi. Keputusan menunjukkan bahawa cadangan rangka kerja ini dapat menghasilkan pengetahuan pembelajaran baru yang melibatkan maklumat pembelajaran kompleks.

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LIST OF ABBREVIATIONS

(AI)   -   Artificial Intelligence

(CAT)   -   Constructive Alignment Theory

(DQ)   -   Data Quality

(EAI)   -   Enterprise Application integration

(EII)   -   Enterprise Information Integration

(ETL)   -   Extract, Transform and Load

(KBs)   -   Knowledge Bases

(LMS)   -   Learning Management System

(OE)   -   Ontology Engineering

(OWL)   -   Ontology Web Language

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1   Overview

Learning environment is an environment that provides information that benefits for learning process (Abualrub *et al.*, 2013; Spector and JonathanMichael, 2014). Having a rich learning environment is needed due to its ability to generate new knowledge for learning. The current e-learning system has limited learning environment, for example moodle e-learning system only provides information on course material and student involvement either in forum or task, while the student detail information is not stored in the moodle but stored in Student information system. Therefore, in order to have good learning environment should provides with more information related to learning. In the context of e-learning environment, the source of information are come from various type of information systems such as teaching and learning online application called e-learning system, academic information management system, student management and payment system, Question Bank System, Subject Courses evaluation system, student registration system, library application system and etc, as called as learning applications which are heterogenous in various aspect (Wang *et al.*, 2011). Heterogeneity aspects on learning environment becoming more widely and various (Bian *et al.*, 2011; Ko and Young, 2011).

There are a lot of heterogeneity aspects (Bian *et al.*, 2011; Huang *et al.*, 2012; Sandborn *et al.*, 2011; Zheng and Terpenny, 2013), this research is focuses on heterogeneity aspect on learning environment. According to comprehensive literature review there are four heterogeneity aspects on learning environment such as heterogeneity learning resources, learning applications, learning information and data. These heterogeneity aspects have causes the difficulty to share and integrate the information and data to gain learning knowledge (Dong-mei *et al.*, 2012; Kim *et al.*, 2011; Wang *et al.*, 2011).

Heterogeneity data representation problem is the one of element in heterogeneity aspects on learning environment. Heterogeneity data representation can cause data conflicts on learning environment. Data conflicts are about data that has same name but different meaning or data has same meaning but different name, this phenomenon called semantic problem. The semantic problem is to be a main problem in existing data integration approach (Sandborn *et al.*, 2011; Zheng and Terpenny, 2013).

Many researchers study on semantic data integration areas to handle the problem about heterogeneity of data, a lot of technology architectures and frameworks produce from this research. Existing semantic data integration approaches just tackle on heterogeneity data types, data structure, and database heterogeneity. However, they still have many problems on semantically aspects specific on semantic interoperability, semantic relationship and semantic meaning between data sources that still to be hot issues in the present (Kienast and Baumgartner, 2011; Sandborn *et al.*, 2011; Zheng and Terpenny, 2013). There has been less research study semantic data integration on the learning environment, where the existing research mostly done in the enterprise domain and business environment (Curl and Fertalj, 2009; Dirgahayu *et al.*, 2008; Jin and Zhao, 2013; Kokemueller and Weisbecker, 2010).

1.2   Background of the Problem

In current learning environment, there are many applications that support the learning process. The increasing demand to share learning information between existing learning resource systems on learning environment is to be the current needs (Arch-int and Arch-int, 2013). However, current learning applications with specific purposes are developed with different application design and with various data model representations. These situations can cause the heterogeneity problem and make every individual learning application does not have the capability to integrate data and information learning to gain learning knowledge (Kim *et al.*, 2011; Wang *et al.*, 2011).

Heterogeneity aspects are the main problem on learning environment. There are a lot of heterogeneity aspects on learning environment, such as type of learning information, database system, application system, data structure, data representation and many more aspects (Bian *et al.*, 2011; Ko and Young, 2011). The one of heterogeneity aspects namely data representation produce data conflicts on different data sources. Data conflicts are about data that has same name but different meaning or data has same meaning but different name. This phenomenon produce semantic problem, they are semantic interoperability and semantic relationship. These problem is to be a main problem in existing data integration approach (Sandborn *et al.*, 2011; Zheng and Terpenny, 2013).

Existing semantic data integration frameworks still have weaknesses and there has been less research done on data integration of the semantic aspect in learning environment, existing research mostly done in the enterprise domain and business environment (Curl and Fertalj, 2009; Dirgahayu *et al.*, 2008; Jin and Zhao, 2013; Kokemueller and Weisbecker, 2010). A lot of existing semantic data integration frameworks just tackles on heterogeneity of data type, data structure, and database system. But they still have many problems on semantically aspects specific on semantic interoperability, semantic relationship and semantic mapping between data sources, and these problems still to be hot issues in the present (Bergamaschi *et*

al., 2011; Berkani *et al.*, 2012; Bian *et al.*, 2011; Dong-mei *et al.*, 2012; Fernandes *et al.*, 2010; Guo and Zhang, 2009; Zheng and Terpenny, 2013).

1.3   Statement of the Problem

Current learning environment consists of numerous learning applications with heterogeneity data that leads to limited capability to share data and information with other learning applications and these conditions can cause semantic problem (such as semantic interoperability and semantic relationship) to communicate, integrate and share learning information to gain learning knowledge.

Main research question: *"How to design a framework for semantic data integration to handle heterogeneity problem on learning environment?"*

From the main research question, the following questions are addressed:

1. What are the heterogeneity aspects on learning environment?
2. What are the existing semantic data integration frameworks that have been implemented?
3. How to design Ontology-based semantic heterogeneous data integration framework on learning environment to handle heterogeneity and semantic problem?
4. How to develop Learning ontology to support the Ontology-based semantic heterogeneous data integration framework?
5. How to validate the learning ontology?
6. How to map the heterogeneity data with the semantic perspective?
7. How to verify an Ontology-based semantic heterogeneous data integration framework using ontology to handle semantic problem on learning environment?

8. How to measure the Ontology-based semantic heterogeneous data integration framework to integrate heterogeneity data to solve semantic problem on learning environment?

1.4   Objectives of the Study

The specific aim of this research is to propose an Ontology-based semantic heterogeneous data integration framework using ontology to handle data heterogeneity on learning environment.

This research has the following objectives:

1. To investigate the heterogeneity aspects on learning environment and existing semantic integration frameworks.
2. To propose the Ontology-based semantic heterogeneous data integration framework to handle heterogeneity and semantic data problem on learning environment.
3. To validate the semantic aspect in the proposed framework that able to integrate various learning information to produce new learning knowledge.

1.5   Scope of the Study

In order to produce Ontology-based semantic heterogeneous data integration framework, this study focused on the scope as follows:

1. This research focuses on data heterogeneity between structural data sources (database), heterogeneity in data representation, heterogeneity on information learning, heterogeneity on learning applications, semantic interoperability between data sources, semantic relationship between data sources and semantic meaning between data sources on learning environment.

2. Types of learning data that are integrated in this framework are teaching and learning experiences data, assessment task data, learning outcomes data and student result data based on constructive alignment theory.

3. This research focuses on ontology approach in Ontology-based semantic heterogeneous data integration framework.

4. Student's performance data, lecturer's activities data, and teaching-learning data are based on online activities using applications system.

5. The verification process of this research uses the teaching and learning experiences data and assessment data from the Moodle e-learning application employed in UTM for semester I in 2013-2014. Learning outcomes and student result data that are used in this research are SCSJ2013_Section3, SCSP1103_Section2, SCSP1103_Section8, and SCSP1103_Section9.

6. The validation process of this research focuses on completeness and consistency criteria. The performance and security criteria have also been beyond the scope of this research and have been identified as a future research direction in Chapter 8.

1.6 Significance of the Study

A lot of applications developed on learning environment, such as online teaching and learning application called e-learning system, academic information management system, student management and payment system, Question Bank System, Subject Courses evaluation system, student registration system, library application system and other learning applications (Wang *et al.*, 2011). The increasing demand to share learning information between existing learning applications on learning environment is to be the current needs (Arch-int and Arch-

int, 2013). Semantic approach using ontology knowledge is the best solution to solve heterogeneity aspects and semantic problems on learning environment (Alcaraz Calero *et al.*, 2010; Bittner *et al.*, 2005; Dong-mei *et al.*, 2012; Schulz and Martínez-Costa, 2013; Sonsilphong and Arch-int, 2013). The Ontology-based semantic heterogeneous data integration framework contributes to learning environment in which it able to integrate various learning applications to gain new knowledge and support the decision making process in the learning organization to improve the system, behaviour, quality and goal of organization. Without the proposed framework, the decision making is difficult and become costly.

The ultimate goal of this research is to create a self-organizing framework, which does not only understand the data and information, but also has the intelligence to understand when to use the knowledge. The essential contributions of this research are Ontology-based semantic heterogeneous data integration framework and learning ontology as the beginning point to support the intelligence era in order to produce valuable and rich information called knowledge. With ontology knowledge development on this framework, cognitive interpretation of information with adding semantic relationship in the knowledge representation can be made clear. This research have an ultimate contribution because this is a reusable framework and knowledge that can be adopted, edited and improved base on vision and mission in other organizations.

1.7 Structure of Thesis

This thesis is divided into 8 main chapters: chapter 1 for introduction, chapter 2 is the literature review section, chapter 3 for the description of research design and methodology, chapter 4 is to detail explanation to develop learning ontology for Ontology-based semantic heterogeneous data integration framework, chapter 5 for the semantic data mapping process as a standardization process in Ontology-based semantic heterogeneous data integration framework. Chapter 6 is to conduct semantic data integration process, chapter 7 is to measure and validate the Ontology-

based semantic heterogeneous data integration framework based on quality matric criteria, chapter 8 is the conclusion and future works section. The content of the chapters are briefly illustrated as the followings:

Chapter 1

Chapter 1 introduces the problem background of this research, statement of the problem, objective of the study, scope of the study, significance of the study and structure of thesis.

Chapter 2

Chapter 2 discusses the fundamental theories of the thesis derived from previous works. Heterogeneity on learning environment, ontology, investigate the existing semantic data integration frameworks, semantic data mapping on data integration and data integration measurement method.

Chapter 3

Chapter 3 is devoted for the description of the research design and methodology, which is used to solve the problems outlined in chapter 1. This chapter also gives the detail mapping between research problems, research phases, research chapter, research questions, research activities and research objectives.

Chapter 4

Chapter 4 is a chapter dedicated to explain more detail the development of learning ontology. The systematic step to develop learning ontology is using custom ontology development methodology as the one of contribution of this research. The result of this chapter is the learning ontology as a main part on Ontology-based semantic heterogeneous data integration framework. The learning ontology result

combined with semantic data mapping file to conduct semantic data integration process in the final part in this framework.

Chapter 5

Chapter 5 is another contribution of this research as mentioned before is to conduct semantic data mapping process. There are four main activities on this section, the first activity is to identify the heterogeneity of data schemas and learning information on every data source, the second activity is to construct the semi-automatic data mapping using D2RQ, the third activity is to customize the data mapping files and the fourth activity is to consolidate the data mapping files. The final result of this chapter is to produce semantic data mapping file that to combine with the learning ontology to get all data and information in data sources to be knowledge.

 Chapter 6

Chapter 6 is to conduct semantic data integration process to verify the Ontology-based semantic heterogeneous data integration framework with the real data. Semantic data integration process involves the real learning data from every data source on learning environment. Semantic data integration process are involves three data sources from three different learning applications, there are Question Bank system, Student Grading system and Moodle E-learning System. The purpose of this chapter is to real test the Ontology-based semantic heterogeneous data integration framework whether in accordance with the objectives of this research.

Chapter 7

Chapter 7 describes in details about validation steps and method to assess the Ontology-based semantic heterogeneous data integration framework based on quality data criteria. In this chapter shows the matric quality factors to address the consistency and completeness criteria with the schema and mapping factor. Every

quality factor in quality matric factor produces specific formula to assess the Ontology-based semantic heterogeneous data integration framework to get quality value of every quality factor.

Chapter 8

Chapter 8 is to covers conclusion and future works of the conducted research. This chapter is important to give a clear picture about the linkage between thesis goal and result that has been achieved on the thesis and also the limitation that need to be carried out in the future. The future work is presented as well to give an opportunity to other researchers in the future.

1.8   Summary

Growth of application and data on learning environment produce heterogeneity aspects on learning environment. Heterogeneity aspects are about collection of numerous applications with various learning sources and learning information that have heterogeneity of data in every learning application. The need of data sharing and integration makes integration process to be very importance and famous in recent days. Come out with heterogeneity phenomenon, data integration process need to improve and using the new approach to raise that problem. Existing semantic data integration frameworks still have lacks and weaknesses to handle the semantic problem (semantic interoperability, semantic relationship and semantic meaning between data sources). Semantic problem on data heterogeneity is the main issues to be tackle now. Development ontology as a new approach in data integration area is the best solution to tackle the problem and produce a new result, the valuable information that has intelligence meaning calls knowledge. This research goal is to develop Ontology-based semantic heterogeneous data integration framework for learning environment and build learning ontology to handle the semantic problem and produce intelligence information call learning knowledge.

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