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Development of Breast Cancer Ontology Based on Hybrid Approach

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***Abstract*— Cancer can be defined as uncontrolled growth of the cells in the human body and can cause in death if the spread is uncontrollable. As the huge amount of breast cancer data available, the integration of data from difference sources becomes one of the challenges in healthcare. The increasing number of data will make the data disorganised, hard to acquire information and share knowledge from a huge database. In recent years, ontology has become more visible within healthcare area. Ontology is a new method designed to improve data integration in a complex database. Ontology integrates and extracts the data from difference sources. There are three ontology methods for data integration, which are single ontology method, multi-ontology method and hybrid ontology method. Hybrid ontology method is a better method as compared to single ontology and multi-ontology. Therefore, this study focused on data integration based on hybrid ontology approach for breast cancer.**

Keywords — Hybrid ontology, Data Integration, Breast Cancer

I. Introduction

As we know, breast cancer is a main cause of mortality in the world. Cancer is an uncontrolled cell growth in human body. Breast cancer forms in tissues of the breast, usually the ducts (tubes that carry milk to the nipple) and lobules (glands that make milk) (MedicineNet, 2011). It may also occur in other areas of the breast. Breast cancer occurs in both men and women, although the breast cancer cases on male are rare. Figure 1 show the percentage for ten cancers that are the highest in peninsular Malaysia in 2006 (Ministry Of Health Malaysia, 2006).

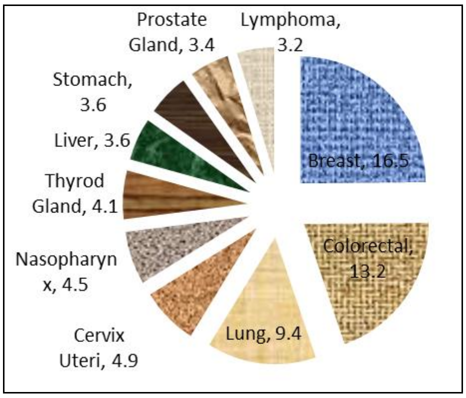


Fig 1. The percentage for ten cancers that is highest in peninsular Malaysia in 2006
Source: Ministry Of Health Malaysia, 2006

In Peninsular Malaysia, as much as 21,773 cases of breast cancer have been diagnoses among Malaysian population in year 2006. These cases of breast cancer were registered in National Cancer Registry in Malaysia. 9,974 cases in men and 11,799 cases among the women were recorded. Five cancers that normally reported among the population in peninsular Malaysia in 2006 are breast, colorectal, lung, cervix and nasopharynx cancer. The abundance of data which come from various sources may hinder the retrieving process of useful knowledge. Due to that reason, ontology approach in data integration has attracted the attention due to its ability in solving various types of heterogeneous problems. Ontology enhanced the communication between human and machine by formalizing the word meanings through related concepts (Using *et. al*, 2010). In this study, ontology was uses to integrate the breast cancer dataset that come from different data sources. In general, ontology is used with well-defined term scheme to resolve the semantic problems (Buccella *et. al*, 2003; Wache *et. al*, 2001). The main purpose of ontology usage in this study was to integrate the cancer data from different sources into a single database and resolve the terminological difference problem of data attribute.

II. Overview of Ontology

Ontology is defined as formalizing the word meanings through related concepts for a better communication between human and machine (Using, *et. al*, 2010). Ontology has two important components, namely entity and relationship, which need to be stated to create ontology. Generally, the structure of ontology is in a hierarchy shape that is formed by the relationship between class and relation, from general to more specific (Guangfei, *et. al*., 2007). According to Nimmagadda *et. al*, (2005), ontology will integrate the data from different sources to store in a database. Figure 2 shows the hierarchy structure of ontology derived by integrating the data with similar characteristic.

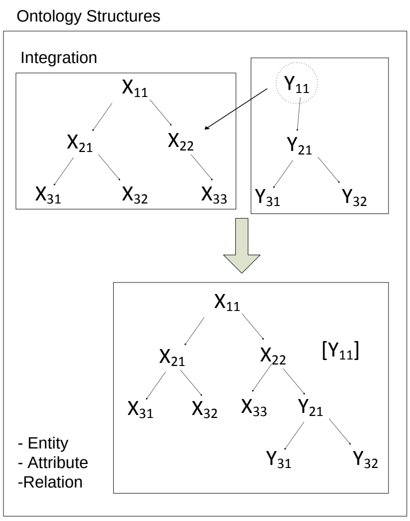


Fig 2. Ontology Structure

Table I shows the development steps of ontology that was carried out by past researchers. There were no specific steps for developing ontology. Various development ontology steps have been introduced by researchers such as Guangfei, *et. al*, 2007; Natalya and Deborah, 2011; Bermejo, 2007; Xiufen and Yabin, 2011.

TABLE I. ONTOLOGY DEVELOPMENT STEP

Researcher	**Development step**
Rajpathak and Chougule (2011)	• Pre-development phase ✓ Ontology specification document ✓ Determination of data and knowledge sources ✓ Knowledge acquisition • development phase ✓ semantic structure ✓ ontology formalization ✓ ontology validation • post-development phases ✓ ontology documentation ✓ ontology maintenance and update
Bermejo (2007)	• Determine the domain and the scope or purpose of your ontology • Know your sources: documents, experts and existing ontologies • Build the ontology ✓ Enumerate important terms ✓ Define concept taxonomies ✓ Define relations, attributes and instances ✓ Define axioms, rules and functions
Leung *et. al*, (2011)	• Preparation, ✓ identify purpose, scope, domain expert • Analysis, ✓ conceptualization ✓ categorize similar key ✓ identify linkage points ✓ build a basic ontology ✓ integrate knowledge modules into one ontologies • Design, ✓ build knowledge module for used category ✓ assemble all unused key terms back to the ontology • Implementation ✓ coding • Maintenance ✓ usability testing, add new knowledge
Buccella *et. al*. (2003)	• building the shared vocabulary ✓ analysis of information sources, ✓ search for terms (or primitives) ✓ defining the global ontology • building local ontologies ✓ analysis of information source ✓ defining the local ontologies • defining mappings
Natalya and Deborah (2011)	• Determine the domain and scope of the ontology • Consider reusing existing ontologies • Enumerate important terms in the ontology • Define the classes and the class hierarchy • Define the properties of classes—slots • Define the facets of the slots • Create instances
Uschold and	• Identify purpose

King (1995)	• Building the ontology ✓ Ontology capture ✓ Coding ✓ Integrating existing ontologies • Evaluation • Documentation
Xiufen and Yabin (2011)	• Construction of global ontology ✓ Identify field of ontology ✓ Extract term of the field ✓ Define global ontology by identify class hierarchy, class attribute and relationship between classes • Construction of local ontology • Mapping between global ontology and local ontology ✓ Concept mapping ✓ Attribute mapping ✓ Role mapping • Mapping between local ontology and data source ✓ Mapping between concept of local ontology and the relational database ✓ Mapping between attribute of local ontology and the relational database ✓ Mapping between role of local ontology and the relational database

III. Ontology Integration Approach

There are three methods proposed to develop ontology based data integration as stated by Cruz and Xiao, (2005); Gagnon, (2007); Xiufen and Yabin (2011); and Wache *et. al*, (2001), which are single ontology method, multi-ontology method and hybrid ontology method. Figure 3 presents those three methods of ontology based integration.

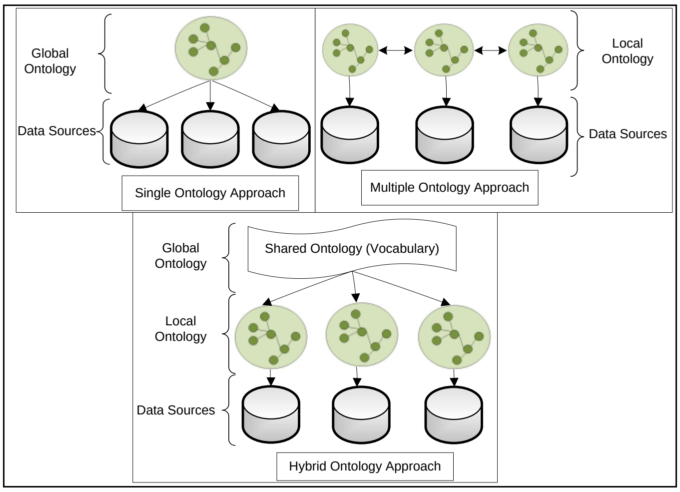


Fig 3. Ontology based integration method

Single ontology is using a global ontology which related to all data sources. The development of single ontology is simple, however, single ontology only suitable to be used if the view of data sources are almost the same. Besides, the adding and removing a data source will affect the global ontology.

Every data sources in multiple ontology approach have its own local ontology. Therefore, the adding and removing a data source can be done easily without affect to others ontology. Even so, the semantic problems may occur due to lack of common vocabulary.

Hybrid ontology approach overcomes the weaknesses found in previous approaches and retains the advantages. Hybrid ontology develops local ontology for each data source and consequently develops the global ontology using common terms found in the domain. The use of common vocabulary makes the comparison between local ontology become simple and solved semantic problems. Moreover, it's easy to add or remove the data sources.

IV. Methodology for Ontology Development

This study refers to development approach defined by Xiufen and Yabin, 2011, because the development steps are suitable for develop breast cancer ontology. In addition, the development of hybrid ontology in their study shows with clearer step compared to others studies.

The ontology development steps for this study are discussed below. According to figure 4, methodology for ontology development in this study can be divided into three phase which is preparation, hybrid ontology process and development of ontology. First phase for this study is preparation which is domain and scope of ontology need to determine. All the related information need to be identified such as the data, user and software that will use in the study. Besides, domain knowledge needs to be identified whether from documentation, expert and existing ontology. This is important to make an accurate ontology. The domain knowledge for this study is getting from several ways such as domain expert who is a medical officer and documentation taken from article, journal and websites.

The next step is ontology development, which we will use hybrid ontology approach to develop breast cancer ontology. The steps to build ontology by using hybrid ontology approach are discussed below.

i. Development of global ontology
Global ontology is built by identifying public terms and vocabulary in the breast cancer domain. The identified terms is used to define the concept and attribute of global ontology.

ii. Development of local ontology
Local ontology is a semantic description of the data source. Each source of data has its own ontology.

iii. Mapping between global ontology and local ontology
Ontology mapping between the global ontology and local ontology is divided into three part namely concept mapping attribute mapping and role mapping.

iv. Mapping between local ontology and data source
There are three steps that must be taken to do the mapping of local ontology and data source. The first step is to establish the mapping concept between local ontology and data source. Meanwhile, the second step is mapping between attribute of local

ontology and attribute names in the dataset. Finally, the role mapping between local ontology and data source will be done.

The last phase is development of ontology using protégé 4.2 and OWL language. Protégé is chosen because protégé is a free, provides a user with a suite of tools to construct domain models with ontology. It also supports the creation and visualization of ontology.

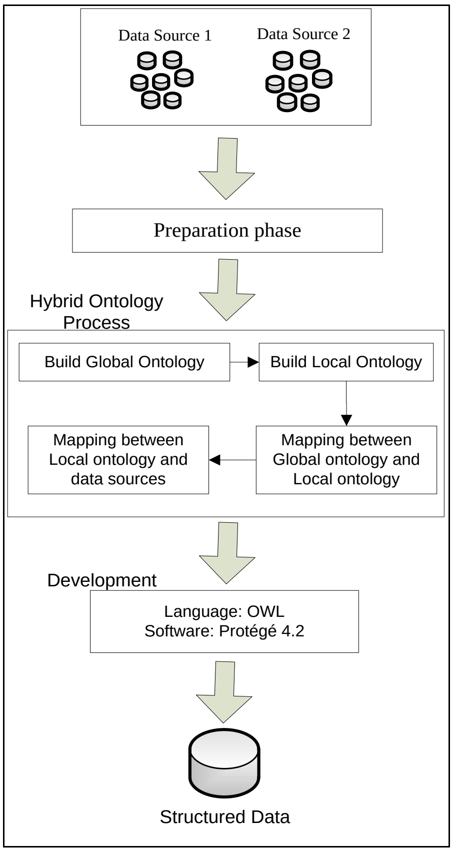


Fig 4. Ontology development steps

V. RESULT

This study uses Wisconsin Breast Cancer Dataset to develop breast cancer ontology. Breast cancer ontology will be implemented using OWL language by protégé 4.2 software. Breast cancer ontology is developed to give an effective of sharing knowledge, increase data quality, facilitate domain understanding and provide knowledge for the domain.

Domain knowledge is important to build an accurate ontology and is needed to get a deeper knowledge of the domain. The domain knowledge for this study is getting from domain expert who is used for ontology development purpose by knowing and understand the term of breast cancer used frequently in the domain and the documentation which is very helpful to understand the literature of the domain. The sources of documentation can be getting from website, journal and medical article. By using this way, we can identify the terms that can be used in the study.

In this study, the concept will be represented with rectangle shape, attribute represented with oval shape. Next, fine arrows are used to show the relationship between concepts and attributes, which, the relationship used in this study is 'has a' and the bold arrow shows the relationship between concepts and concepts. Figure 5 show the example of concept, attribute and relationship used.

Fig 5. The representation of concept, attribute and relationship

Next, global ontology will be developed. There are two steps to build global ontology which is identify the terms and use the identified terms to define global ontology. The identified term will be used to define concept and attribute for global ontology. Figure 6 show global ontology of breast cancer.

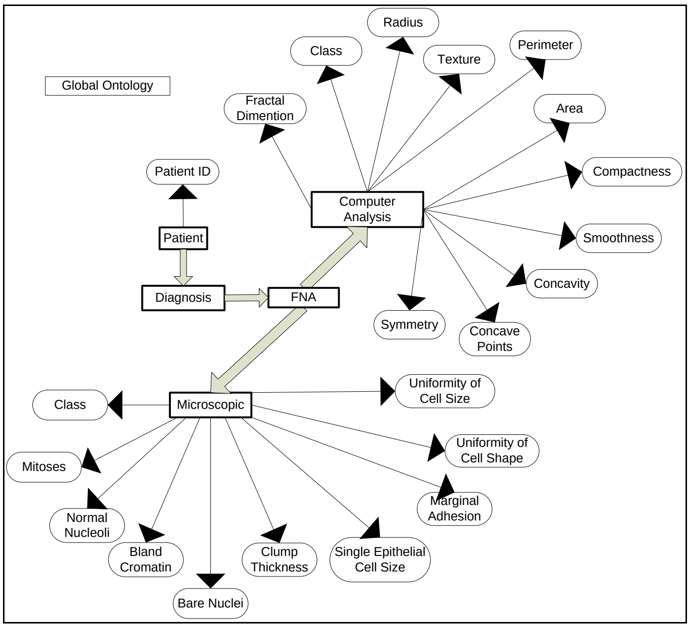


Fig 6. Global Ontology

According to Wolberg, *et. al,* (1995) and Gouda, *et. al,* (2012), the patients will diagnosis using fine needle aspirate (FNA). The digitized image of FNA diagnosis is taken by two method, namely, computer analysis and microscopic. Computer analysis readings are computed by detailed characteristic of the size, texture and form of cell nuclei. The term included in computer analysis is Diagnosis, Radius, Texture, Perimeter, Area, Smoothness, Compactness, Concavity, Concave Points, Symmetry, and Fractal Dimension. Meanwhile, microscopic readings are based on the features of cancer cell which the attribute in microscopic is Clump Thickness, Uniformity of Cell Size, Uniformity of Cell Shape, Marginal Adhesion Single Epithelial Cell Size, Bare Nuclei, Bland Chromatin, Normal Nucleoli, Mitoses, and

Class. With the information gathered, the concept and attribute for global ontology is identified.

Local ontology is the semantic explanation for data sources. Each data source will have they own ontology. The name of data sources will be the concept, meanwhile the attribute in the data sources is defined as class attribute. Figure 7 and Figure 8 show local ontology developed for each dataset.

Dataset1:
{Diagnosis (Patient ID, Diagnosis, Radius, Texture, Perimeter, Area, Smoothness, Compactness, Concavity, Concave Points, Symmetry, Fractal Dimension)}

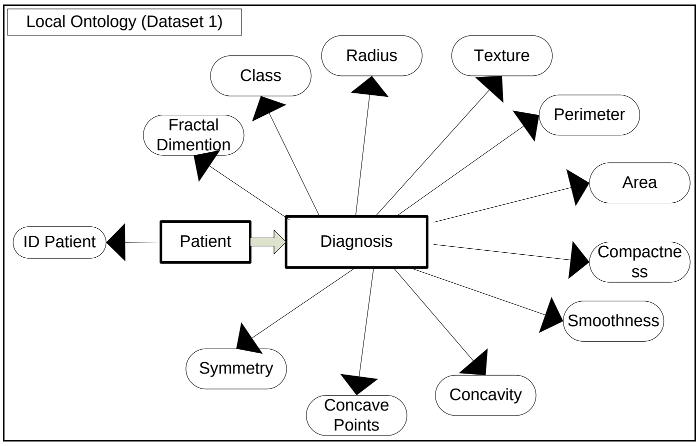


Fig 7. Local Ontology Dataset 1

Dataset2:
{FNA (Sample code number, Clump Thickness, Uniformity of Cell Size, Uniformity of Cell Shape, Marginal Adhesion Single Epithelial Cell Size, Bare Nuclei, Bland Chromatin, Normal Nucleoli, Mitoses, Class)}

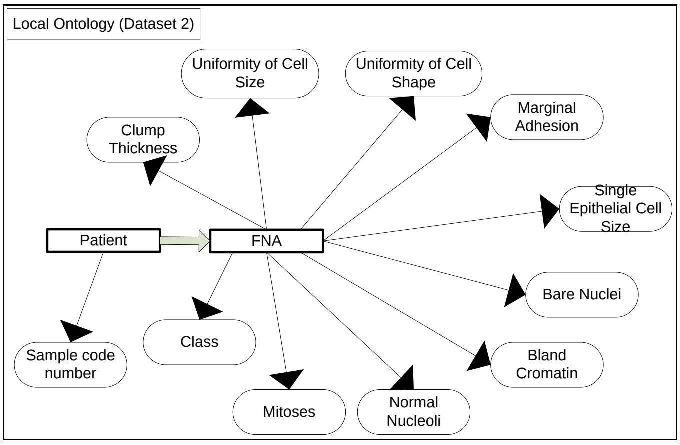


Fig 8. Local Ontology Dataset 2

Mapping between global ontology and local ontology will be divided by three namely concept mapping, attribute mapping and role mapping. Concept mapping will be mapping the concept in local ontology to global ontology. Meanwhile, attribute mapping will be mapping the attribute in local ontology to global ontology. Role mapping is used to combine the concept in the local ontology with the global ontology by mapping the role in the local ontology to global ontology. Table II show the mapping rules from local ontology 1 to global ontology and Table III shows mapping rules from local ontology 2 to global ontology.

TABLE II. MAPPING RULES FROM LOCAL ONTOLOGY 1 TO GLOBAL ONTOLOGY

Rule Name	**Rule**
R1	Diagnosis → Diagnosis
R2	Radius → has.FNA.hasComputerAnalysis.hasRadius
R3	Class → has.FNA.hasComputerAnalysis.Class
R4	Texture → has.FNA.hasComputerAnalysis.hasTexture
R5	Perimeter → has.FNA.hasComputerAnalysis.hasPerimeter
R6	Area → has.FNA.hasComputerAnalysis.hasArea
R7	Compactness → has.FNA.hasComputerAnalysis.hasCompactness
R8	Smoothness → has.FNA.hasComputerAnalysis y.hasSmoothness
R9	Concavity → has.FNA.hasComputerAnalysis.hasConcavity
R10	Concave Point → has.FNA.hasComputerAnalysis.hasConcavePoint
R11	Symmetry → has.FNA.hasComputerAnalysis.hasSymmetry
R12	Fractal Dimension → has.FNA.hasComputerAnalysis. hasFractalDimension
R13	hasDiagnosis → hasDiagnosis

TABLE III. MAPPING RULES FROM LOCAL ONTOLOGY 2 TO GLOBAL ONTOLOGY

Rule Name	**Rule**
R1	FNA → FNA
R2	Clump thickness → hasMicroscopic.hasClumpthickness
R3	Uniformity of Cell Size → hasMicroscopic.hasUniformityofCellSize
R4	Uniformity of Cell Shape → hasMicroscopic.hasUniformityofCellShape
R5	Marginal Adhesion → hasMicroscopic.hasMarginalAdhesion
R6	Single Epithelial Cell Size → hasMicroscopic.hasSingleEpithelialCellSize
R7	Bare Nuclei → hasMicroscopic.hasBareNuclei
R8	Bland Chromatin → hasMicroscopic.hasBlandChromatin
R9	Normal Nucleoli → hasMicroscopic.hasNormalNucleoli
R10	Mitoses → hasMicroscopic.hasMitoses
R11	Class → hasMicroscopic.hasClass
R12	hasFNA → hasDiagnosis.hasFNA

There were three steps that need to use to establish the mapping. The first step is mapping the concept with the data source which is the name of the data source used. Meanwhile, the second step is to map the attribute between the local ontology and the name of attribute in the data source. Lastly, the role in local ontology will be mapping with the primary key of the data. Table IV show the mapping rules from Data source 1 to local ontology and Table V shows mapping rules from Data source 2 to local ontology.

TABLE IV. MAPPING RULES FROM DATA SOURCE 1 TO LOCAL ONTOLOGY

Rule Name	Rule
R1	Patient → Patient
R2	Diagnosis → Diagnosis
R3	Patient.PatientID → PatientID
R4	Diagnosis.Class → Class
R5	Diagnosis.Texture → Texture
R6	Diagnosis.Perimeter → Perimeter
R7	Diagnosis.Area → Area
R8	Diagnosis.Compactness → Compactness
R9	Diagnosis.Smoothness → Smoothness
R10	Diagnosis.Concavity → Concavity
R11	Diagnosis.ConcavePoint → Concave Point
R12	Diagnosis.Symmetry → Symmetry
R13	Diagnosis.FractalDimension → Fractal Dimension
R14	Diagnosis.Radius → Radius
R15	< Patient.PatientID> → hasDiagnosis

TABLE V. MAPPING RULES FROM DATA SOURCE 2 TO LOCAL ONTOLOGY

Rule Name	Rule
R1	Patient → Patient
R2	FNA → FNA
R3	Patient.Samplecodenumber → Sample code number
R4	FNA.ClumpThickness → Clump Thickness
R5	FNA.UniformityofCellSize → Uniformity of Cell Size
R6	FNA.UniformityofCellShape → Uniformity of Cell Shape
R7	FNA.MarginalAdhesion → Marginal Adhesion
R8	FNA.SingleEpithelialCellSize → Single Epithelial Cell Size
R9	FNA.BareNuclei → Bare Nuclei
R10	FNA.BlandChromatin → Bland Chromatin
R11	FNA.NormalNucleoli → Normal Nucleoli
R12	FNA.Mitoses → Mitoses
R13	FNA.Class → Class
R14	<Patient.Samplecodenumber> → hasFNA

Next, global ontology developed by using software protégé 4.2 with OWL as language. Protégé is used in this research because it’s supports the creation and visualization of ontology in various representation formats. Protégé also enables users to build ontology for the Semantic Web. We must define the relation of class in the tree structure, In order to build the ontology file, which mainly refers to the hierarchical relations that can be represented the word ‘‘subClassof’’. Figure 9 and figure 10 respectively show OWL class in a hierarchical fashion for breast cancer ontology and the visualization for the developed ontology.

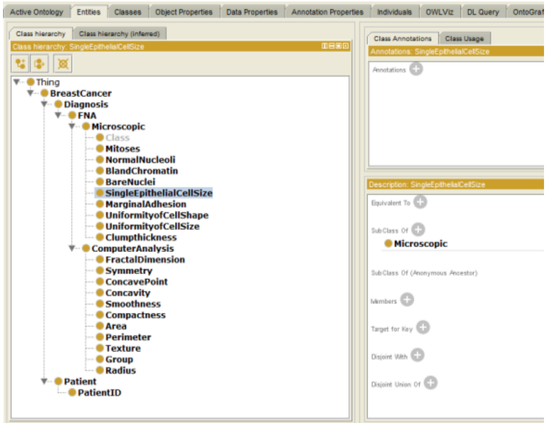


Fig 9. OWL class for breast cancer ontology

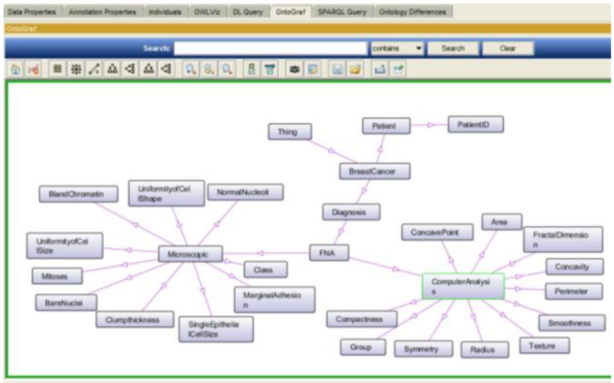
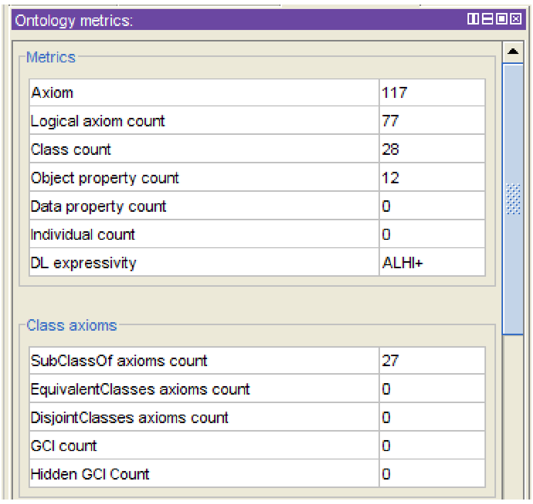


Fig 10. Visualization for the developed ontology

Ontology metrics is a representation of an important approach in ontology evaluation. Ontology metrics is a summary of the ontology developed to verify and state statistics on the number of classes, relationships, attributes, instances, objects and features for developed ontology (*National Center for Biomedical Ontology*, 2012). By evaluating the ontology, we can identify the part which need more care and may cause the problem. Protégé is an important tool in evaluating the ontology (Garcia, J. *et. al*, 2010). Figure 11 shows ontology metrics of breast cancer ontology in this study.



Ontology metrics:

Metrics

Axiom	117
Logical axiom count	77
Class count	28
Object property count	12
Data property count	0
Individual count	0
DL expressivity	ALHI+

Class axioms

SubClassOf axioms count	27
EquivalentClasses axioms count	0
DisjointClasses axioms count	0
GCI count	0
Hidden GCI Count	0

Fig 11. Ontology metrics

VI. Discussion

Ontology development method introduced by Xiufen and Yabin, 2011, is referred since the development step is clearer and suitable to use in this study. However, ontology modeling in the study had some differences with ontology introduced in the study Xiufen and Yabin, 2011. There six criteria that has been identified which are development phase, ontology approach, detail of introduced ontology, ontology evaluation and ontology implementation. As stated in table VI, this study covers all of the ontology development phases which are predevelopment, development and post-development ontology. Thus, development steps done are more systematic and organized which make ontology development proses become more effective and efficient. Hybrid ontology approach has all the advantage of single ontology and multi-ontology approach and overcome their shortcoming. The changes in local ontology will not affecting global ontology. In addition, hybrid ontology new sources can easily be added without the need of modification in the mappings. Data integration based hybrid ontology approach can give an effective of sharing knowledge, increase data quality, facilitate domain understanding and provide knowledge for the domain.

TABLE VI. BENCHMARK OF ONTOLOGY DEVELOPMENT METHOD

	Development phase			**Approach**	**Detail of methodology**	**Data**	**Evaluation**	**Implementation**
	Pre	**Development**	**Post**					
Fatimatufaridah	√	√	√	Hybrid ontology	A lot	Dataset and website	Ontology metrics, domain expert, reasoner and application	Protégé 4.2 and OWL
Rajpathak and Chougule (2011)	√	√	√	Single ontology	Moderate	dataset	Empirical assessment and application	Protégé-2000, OWL and RDF
Bermejo (2007)	χ	√	χ	Single ontology	A lot	General terms	Check the class hierarchy and class definitions	-
Leung *et. al*, (2011)	√	√	√	Integrate existing ontology	Moderate	-	Application, query and domain expert	Protégé, RDF and OWL
Buccella et. al. (203)	χ	√	χ	Hybrid ontology	A little	General terms	-	-
Natalya and Deborah (2011)	χ	√	χ	Single ontology	A lot	General terms	-	Protégé-2000
Uschold and King (1995)	χ	√	χ	Single ontology	A little	-	Specifications, queries and applications	KSL ontology editor
Xiufen and Yabin (2011)	χ	√	χ	Hybrid ontology	A lot	Dataset	Searching platform	-
Wang and Ye (2009)	χ	√	χ	Hybrid ontology	A little	-	Query	OWL

VII. Conclusion

The contribution of this study can be seen in methods of ontology development. Although there some difference from study by Xiufen and Yabin, (2011), developed ontology in this study are able to give a better understanding of the data as well as solve semantic problems. In addition, ontology development steps introduced in this study is more complete and organized by having a clear development which is predevelopment, development and post-development. Method of ontology development done in this study is simple and systematic. This study has successfully solved the semantic heterogeneous problems by using hybrid ontology approach for data integration as well as gives a better understanding of the domain. Next, mapping file will be done to map the database to the ontology format using an open source platform for accessing database as virtual read only RDF graph (D2RQ).

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