Article

Object Oriented and Ontology Alignment Patterns based Expressive Mediation Bridge Ontology (MBO)

Journal of Information Science
1–22

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DOI: 10.1177/0165551510000000
jis.sagepub.com

Wajahat Ali Khan
Kyung Hee University, South Korea

Muhammad Bilal Amin
Kyung Hee University, South Korea

Asad Masood Khattak
Zayed University, UAE

Maqbool Hussain
Kyung Hee University, South Korea

Muhammad Afzal
Kyung Hee University, South Korea

Sungyoung Lee
Kyung Hee University, South Korea

Eun Soo Kim
Kwangwoon University, South Korea

Abstract
Semantic web is dependent on extensive knowledge management by inter linking resources on the web using matching techniques. This role is played by the progressing domain of ontology matching, by introducing ontology matching tools. The focus of these matching tools is limited to matching techniques and automation only, rather than expressive formal representation of alignments. We propose Mediation Bridge Ontology (*MBO*), an expressive alignment representation ontology used to store correspondences between matching ontologies matched by our ontology matching tool, System for Parallel Heterogeneity Resolution (SPHeRe). The *MBO* utilizes object oriented design patterns and the proposed ontology alignment design patterns to provide extendibility and reusability factors to SPHeRe system. We compared our proposed system with existing systems using Coupling Factor (COF), Number of Polymorphic methods (NOP), and Rate of Change (RoC) metrics to support extendibility and reusability. These factors contributes in the overall objective of interoperability for knowledge management in the semantic web.

Keywords
Ontology; Design Pattern; Matching; Interoperability; Semantics

Corresponding author:
Sungyoung Lee, Department of Computer Engineering, Kyung Hee University, Seocheon-dong, Giheung-gu, Yongin-si, Gyeonggi-do, Republic of Korea, 446-701
sylee@oslab.khu.ac.kr

1. Introduction

The continuous evolution of heterogeneous data repositories is a major hindrance in the way of Semantic Web infrastructure to facilitate mashup-like information sharing. Ontology matching has made measurable progress to resolve semantic heterogeneities among these heterogeneous data repositories for ontology merging, query answering, or data translation [1]. Ontology Alignment Evaluation Initiative[1] (OAEI), a benchmarking initiative, carries out annual campaigns for the evaluation of the ontology matching tools [2]. In the past few years, OAEI evaluated several ontology matching systems; some of these remained in spotlight for many years. Shvaiko et al. [1] presents a survey of some of the recent matching systems based on their operations and matching approaches. A common behavior among these matching tools is their duration of use that lasts for few years and are replaced afterwards. The main reasons for their replacement is the difficulty in extendibility and reusability of these systems. The structure of matching systems should be extensible enough to accommodate new algorithms based on novel matching techniques, replace previous algorithms if they are non-effective, and utilize combination of existing techniques to build new technique. Therefore, incorporating object oriented design patterns [3] with ontology design patterns in ontology matching tools define the longer adaption of such systems.

Ontology Design Patterns (ODP) support pattern based ontology design [4], and are used to capture common modelling situations, help facilitate ontology development and avoid common mistakes [5]. ODP have evolved from Content Ontology Design Patterns (reusable solutions to recurrent content modelling problems) [6] to Ontology Alignment Design Patterns (used to refine correspondences, by alignment designer or pattern detection algorithm) [7]. Ontology matching algorithms detect simple correspondences by following alignment format that lacks the expressiveness needed to formalize correspondence [8]. Therefore, an approach is necessary to design and develop an extendible and reusable system that provide expressive capability to formalize correspondences. The proposed Mediation Bridge Ontology (*MBO*) based approach incorporates object oriented design patterns combined with ontology alignment design patterns in our ontology matching system, System for Parallel Heterogeneity Resolution (SPHeRe) [9].

The proposed *MBO* ontology is an ontology alignment representation scheme that enables expressiveness to formalize correspondence by utilizing object oriented and ontology alignment design patterns. Ontology matching existing schemes only focus on matching the ontologies and storing their alignments in a format which only describes source and target concepts. There is need to find the alignments using design patterns for providing solutions to the common problems. Also, expressiveness in the storage of correspondence is necessary for multiple reasons. First, expert verifications become easier as the correspondence speaks for itself. The correspondence includes not only the source and target concepts, but the attributes involved in correspondence, the procedure of the alignments, and the confidence value of the alignment. Second, feedback about the matching process and alignment can be easily obtained, that helps in the overall improvement of the system and satisfaction of the users. We developed SPHeRe ontology matching system that incorporates bridge algorithms which are stored in expressive alignment representation format in the *MBO*. Strategy[2] and Mediator[3] design patterns are used from object oriented design patterns, combined with ontology alignment patterns called Pattern Relationship Models (PRM). The PRMs are the ontology alignment patterns that defines the expressive formal representation of the correspondences to be stored in the *MBO*. The proposed system supports collaborative ontology concepts by adding metadata information in alignments stored in the *MBO*. This helps in achieving extendibility and reusability metrics of the overall SPHeRe system.

Benchmarking and systematic evaluation is still progressing in the area of semantic technologies [2]. To evaluate the proposed system extendibility and reusability capabilities, we used Quality Model for Object Oriented Design (QMOOD) approach [10]. The factors that contributed to lack of longer adaptation of the existing ontology matching systems are coupling, polymorphism, and the rate of change. Therefore, we used Coupling Factor (COF), Number of Polymorphic methods (NOP), and Rate of Change (RoC) to evaluate the system with existing system to accomplish extendibility and reusability. This work contributes to the overall objective of interoperability among heterogeneous ontologies.

The rest of the paper is structured as follows: Section 2 addresses the methodologies used by existing ontology matching systems and its comparison with proposed system. The proposed Mediation Bridge Ontology (*MBO*) design and development is described in Section 3. Section 4 explains the integrated approach of object oriented design patterns and ontology alignment design patterns based on *MBO*. Section 5 shows the working model of the system and describes the working mechanism of the different bridge algorithms to populate *MBO*. Section 6 evaluates the proposed system by calculating and comparing values of evaluation metrics with existing systems. Section 7 concludes the paper and provides information about the future work.

2. Related Work

Design patterns provide solution to the common occurring problem, and ontologies domain utilized ontology design patterns to facilitate the ontology development process. One of the semantic technologies potential areas that is focusing on incorporating design patterns as the solution to semantic heterogeneity problem is ontology matching that finds the similarities between concepts. Peigang Xu et al [11] proposed a differentor based similarity matrix creation technique used to integrate different similarities measures. Weights are assigned to various entities of the matching ontologies that are used for aggregation tasks after finding the similarity measures. Another approach proposed Tree Structure Based Ontology Integration (TSBOI) [12] methodology used to integrate ontologies with Document Type Definition (DTD) based tree structure development for ontology mappings. This is further utilized by ontology applications for data sharing purpose. These approaches leads to the development of ontology matching tools/ systems. OAEI provides a platform to introduce state of the art ontology matching tools, but their adaption for limited years and difficulty in extendibility, reusability, and expressive mapping representations defines the future directions for ontology matching tools. Some of these tools and approaches for ontology alignment patterns are discussed in this section.

We selected some ontology matching tools for discussion in this section based on their participation and adaption in OAEI, and also some of the existing state of the art systems. Falcon is one of the ontology matching systems that has shown best results in the first few years of OAEI campaign [13]. It provides fundamental technologies for finding, aligning and learning ontologies [13] by using divide and conquer approach to target large ontologies generating 1: n alignments as output [1]. Although this system is still effective in generating alignments between ontologies due to its matching techniques and also user interface; extendibility and reusability are its two major disadvantages. It is extremely difficult to add new matching techniques and algorithms in the system. Agreement Maker is another ontology matching tool that resolves extendibility issue by displaying the ontologies, supporting several mapping layers visually, and presenting automatically generated mappings for producing the alignments [14] [15]. This system is not scalable for large scale ontologies matching, but provides flexible and extensible framework with a comprehensive user interface. The scalability issue is resolved in its new framework AgreementMakerLight that preserves original Agreement Maker framework with main focus on computational efficiency and handling very large ontologies [16]. AgreementMakerLight competes with the recent OAEI performers, GOMMA and LogMap in large bio-med track, but lacks approach for expressive mapping representation.

GOMMA [17] provides infrastructure for managing matching and evolution of ontologies and its impact on mappings. On the other hand, LogMap is an ontology matching tool that address scalability issue for large ontologies matching and produces almost clean set of output mappings [18]. GOMMA and LogMap demonstrates better accuracy as compare to other systems and were equally matched by another matching tool YAM++. YAM++ matching tool supports self-configuration, extensibility and extensibility in combining individual matchers [19]. It discover mappings using information retrieval techniques and also deals with multi-lingual ontologies matching problems [20]. Most of the ontology matching systems focus on automation and accuracy of results and not on expressive alignment representation using ontology alignment patterns. Zamazal et al. [21] presented a generic framework for ontology pattern detection, generation of instructions and ontology transformation from source ontology to target ontology. Scharffe et al. [7] took a step forward by introducing ontology alignment design patterns representation methods and then create a pattern library to be extended with new patterns. The work also explains transformation of ontologies using ontology alignment patterns. To summarize, existing ontology matching tools and ontology alignment patterns based approaches are unable to reflect a comprehensive system that utilizes object oriented design pattern combined with ontology alignment design patterns and storing the correspondences between matched ontologies into a mapping storage and representation repository. Our proposed *MBO* based ontology matching methodology addresses the existing systems issues in our SPHeRe ontology matching system as an extendible, reusable and expressive mapping representation approach.

3. Mediation Bridge Ontology (MBO)

Ontology mediation techniques provide the platform to necessitate interoperability between heterogeneous ontological descriptions [7]. Mediation is based on the alignments generated between heterogeneous sources, and representation of these alignments play vital role in effective interoperability. Little focus is provided to alignment representation area by the semantic web community [22]. An effort towards representing correspondences as a centralized repository was introduced as bridge ontology [23] [24], but it lacked effectiveness, agility, and realization. Although it provided the base for alignment representation but was never the focus, mainly because accuracy of alignments is given higher priority. *Effective alignment representation results in; (1) efficient ontology translation, (2) format transformations, (3) systems mediation, and (4) easy expert verification and modification.* Therefore, the proposed *MBO* targets effective alignment representations in its design and development process. The design aspect utilizes object oriented as well as ontology alignment design patterns for effective mapping representation in the form of low coupling, high polymorphism, and low rate of change. The MBO not only benefits the ontology alignment storage but also its use in the transformation process between different heterogeneous formats. The scope of MBO is categorized into three aspects; Generalized Mappings, Customized Mappings, and Transformation Logic. Generalized Mappings are the alignments that are generated by matching two ontologies using PRM's. The proposed *MBO* provides the alignment representation scheme using ontology design patterns approach keeping in mind the goals expressed for achieving true interoperability. Customized Mappings are the alignments that are based on the conformance issues handling of organizations. Organizations conformance issues are handled through these mappings by detecting the stale mappings initially in the Generalized Mappings and then replacing them with the new modified mappings. The generalized as well as the customized mappings are converted into transformation logic that is used for conversion among different standard formats. The formal description of these concepts is provided in Section 3.2.

MBO is categorized into two main classes *MediationBridge* and *PatternClass*. *MediationBridge* is divided into syntactic and structural bridge subclasses: *String Matching Bridge, Label Bridge, Synonym Bridge, Polysemous Bridge, Overlap Bridge, Customized Bridge, Children Based Structural Bridge, and Property Based Structural Bridge*. These bridge classes are used to represent the alignments generated from particular algorithms in their specified format. These are dependent on *PatternClass* for structuring the output of the alignment process. *PatternClass* include *MappedSequence, Standard1Class, Standard2Class, Match, MappedClass, ListStandard1,* and *ListStandard2* subclasses. These are used to provide the structure for representation of the alignment in the *MBO*. The overall hierarchy of *MBO* is shown in Fig. 1.

These concepts are related to each other by using object properties, its triples are shown in Table 1. *MediationBridge* class is related through *usesPattern* object property with *PatternClass*. Every subclass of *MediationBridge* use some pattern classes from the *PatternClass* subclasses to define its alignment representation. *OverlapBridge* class is related through *hasSourceClass* and *hasTargetClass* object properties with *Standard1Class* and *Standard2Class* respectively. *Standard1Class* uses *hasSameRelationship* and *consistsMandatoryAttributes* object properties to connect with *Standard2Class* and *MandatoryAttribute* respectively. Based on the previous triples, *OverlapBridge* is related with the *Match* class using *hasRestriction* object property. This makes the complete alignment representation for *OverlapPRM* described in the later section. In the same way, other *MediationBridge* classes defines their pattern to represent alignment in the *MBO*.

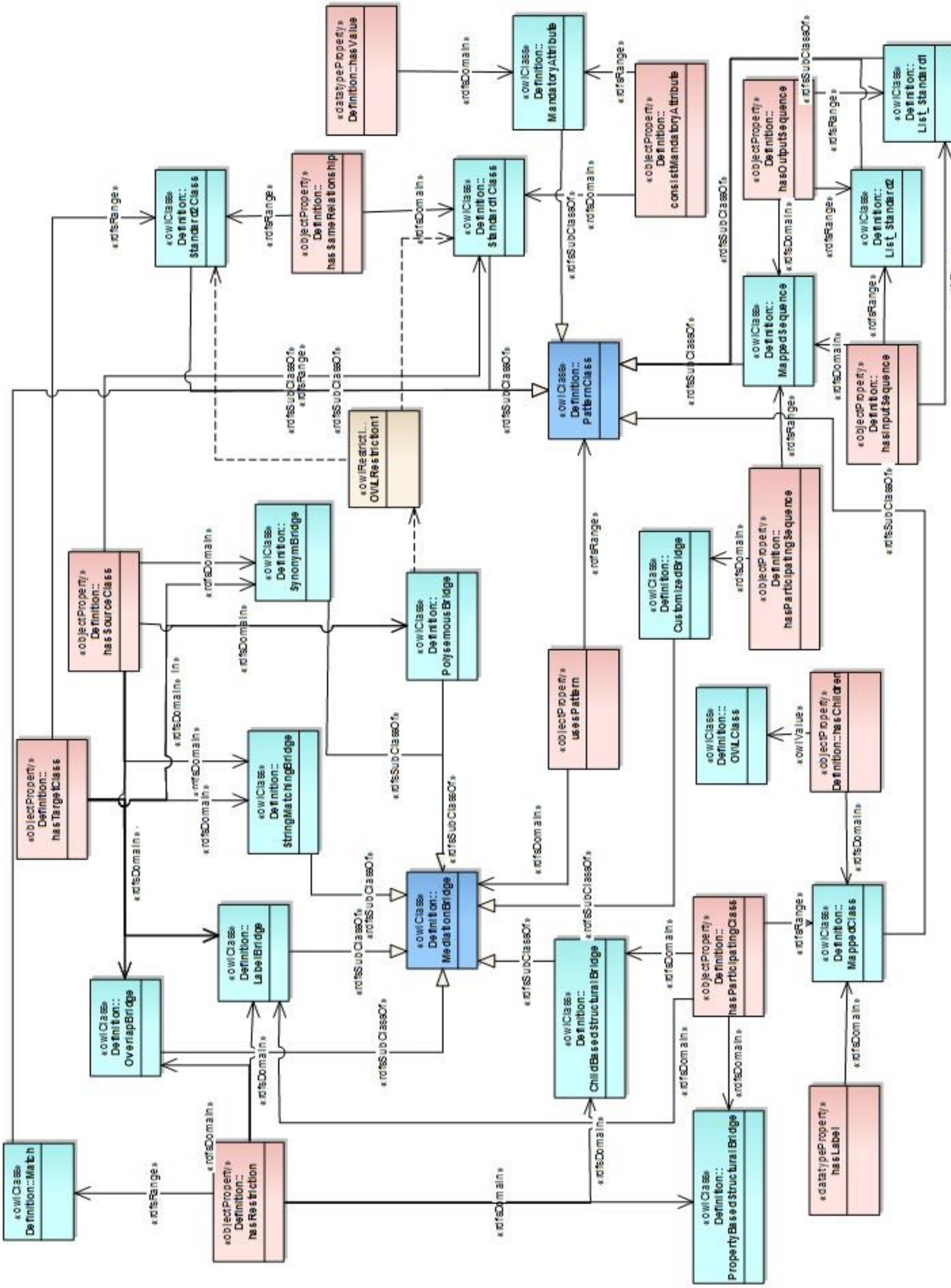


Figure 1: Mediation Bridge Ontology.

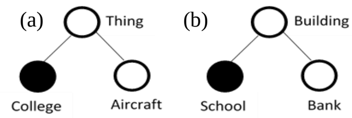
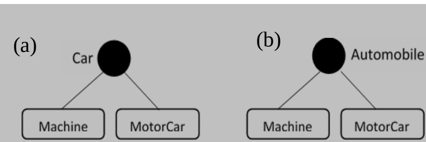
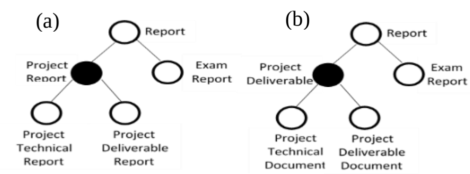
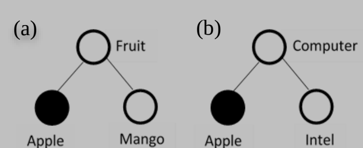
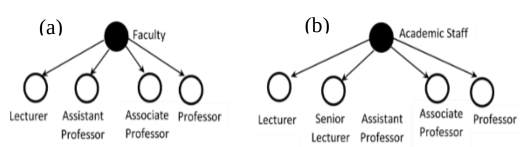
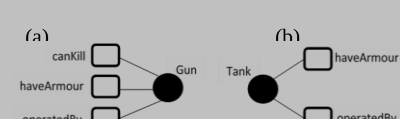
Table 1: Mediation Bridge Ontology Triples.

Domain	Property	Range
Mediation Bridge	usesPattern	PatternClass
Standard1Class	exactMatch	Standard2Class
Customized Bridge	hasParticipatingSequence	MappedSequence
Label Bridge Overlap Bridge Polysemous Bridge String Matching Bridge Synonym Bridge	hasSourceClass	Standard1Class
Label Bridge Overlap Bridge Polysemous Bridge String Matching Bridge Synonym Bridge	hasTargetClass	Standard2Class
Mapped Class	hasChildren	owl:Class
Mapped Sequence	hasInputSequence	ListStandard1 ListStandard2
Mapped Sequence	hasOutputSequence	ListStandard1 ListStandard2
Label Bridge Overlap Bridge PBSB CBSB	hasRestriction	Match
Standard1Class	hasSameRelationship	Standard2Class
PBSB CBSB	hasParticipatingClass	MappedClass
Standard1Class	consistsMandatoryAttribute	MandatoryAttribute

3.1. MBO Bridges Definition, Examples and Scenarios

The *MBO* provides the platform that represents alignments found by different bridge algorithms. These bridge algorithms are defined and explained with real world examples, and scenarios using medical standard ontologies. We use medical standard ontologies as scenarios for the proposed system. The alignments generated and represented in the *MBO* can be used for ontology translation, standard format transformation, and expert verification based on metadata availability about every alignment. One of the bridge algorithms is String Matching Bridge that is used for concepts matching to identify similar concepts in the matched ontologies. These are based on string based matching techniques by considering the sequence of letters of matching concepts. These sequence of letters consideration for matching are based on the intuition that the more similar the strings, the more likely is the chance of the concepts to be similar [25]. Edit distance is one of the technique used for string based matching techniques [26]. Table 2 show the examples and medical ontologies scenario of SPHeRe's bridge algorithms.

Table 2: Mediation Bridge Ontology Concepts, Examples, Scenarios.

Bridge	Example	Medical Ontologies Scenario
Synonym Bridge		[SNOMED CT and Mesh ontology]: Concept DRUG of SNOMED CT ontology which is synonym of concept MEDICINE of Mesh ontology.
Label Bridge		[FMA and NCI ontology]: Concept CARTILAGE CELL of FMA ontology which is similar to concept CHONDROCYTE of NCI ontology based on common label CARTILAGE CELL.
Overlap Bridge		[HL7 and openEHR ontology]: OBSERVATION concept exists in both standard ontologies, and EVALUATION is the sub-concept of OBSERVATION concept in openEHR ontology. Therefore, EVALUATION concept of openEHR ontology can also be transformed to OBSERVATION concept of HL7 ontology while information exchange.
Polysemous Bridge		[SNOMED CT and HL7 ontology]: EVENT concept in SNOMED CT ontology includes concepts that represent occurrences of different events while in HL7 ontology it is any act that has taken place. EVENT concept of SNOMED CT ontology and HL7 ontology are Polysemous in nature.
Child Based Structural Bridge		[HL7 and openEHR ontology]: ENTITY concept of HL7 ontology is equivalent to PARTY concept in openEHR ontology based on their children matched. ENTITY concept has ORGANIZATION, PERSON and DEVICE sub concepts that are mapped with ORGANIZATION, PERSON and AGENT sub concepts of the PARTY concept.
Property Based Structural Bridge		[HL7 and vMR ontology]: OBSERVATION concept belongs to HL7 ontology while OBSERVATION RESULT concept is part of vMR ontology. Both the concepts are similar based on property match. CODE, CODE SYSTEM, and DISPLAY NAME are the common properties between the concepts that leads to the conclusion of property based match.

- Synonym Bridge (Table 2, Row 2) represents identical or closely aligned concepts between different ontologies. College and School are two synonym concepts where College Є O_i (O is ontology) and School Є O_j. Drug and Medicine are synonym concepts from SNOMED CT and Mesh standard ontologies as shown in Table 2.
- Label Bridge (Table 2, Row 3) represents similar concepts based on common information represented as their labels. Car and Automobile are two similar concepts where Car Є O_i and Automobile Є O_j. Car and Automobile both have Machine and Motorcar as their labels. Therefore, their similarity is based on the label match. Cartilage Cell concept of FMA ontology is similar to Chondrocyte concept of NCI ontology based on common label as Cartilage Cell.
- Overlap Bridge (Table 2, Row 4) represents concepts that contains overlapping information that is necessary for data format transformation while information exchange between heterogeneous systems. Project Report and Project Deliverable are two overlapping concepts, as contains most of the information common between them. Taking the example of HL7 and openEHR ontologies, OBSERVATION and EVALUATION are overlapping concepts.
- Polysemous Bridge (Table 2, Row 5) is used to cover same concepts having different meaning cases during ontology matching. Apple concept can represent a Fruit and it can also characterize Computer. Therefore, Apple concept as a Fruit and as a Computer is and illustration of Polysemous bridge. Event concept in SNOMED CT and HL7 has different meaning with same concept name described in Table 2.
- CBSB (Table 2, Row 6) represents concepts and relations/ properties that are similar by comparing similarities between their children. Faculty and Academic Staff are two equivalent concepts based on children match. In HL7 and openEHR medical standard ontologies, Entity (HL7) and Party (openEHR) are similar based on children match.
- PBSB (Table 2, Row 7) represents the concepts that are similar with each other based on their properties. Gun and Tank are two concepts of two separate ontologies similar to each other based on their common properties “haveArmour” and “operatedBy”. Similarly, Observation and ObservationResult concepts of HL7 and vMR ontologies are similar to each other based on their properties.

3.2. Formal Modelling and Representation of MBO

MBO formal modelling using Backus-Naur Form[4] (BNF) is described in this section. MBO constructs are defined by the generalized and customized mappings which are then represented in logic format for transformation among different standards. The generalized mappings are the focus of this paper and it includes the alignment information with the ontology alignment design pattern used for the creation of generalized mappings logic to be used for transformation. The formal definitions of all these concepts as well as the transformation logic based on generalized mappings is presented as follows:

$< MBO > ::= "Generalized\ Mappings :"\ < GM >$

$"Customized\ Mappings:"$ <CM>

$"Transformation\ Logic :" < Logic >$

$< GM > ::= "Alignment\ Info :"\ < AlignInfo >$

"Pattern Relationship Model: " <PRM>

$"Logic\ GM :" < LogicGM >$

$< AlignInfo > ::= "Source\ Entity :"\ < SE >$

"Target Entity : " <TE>

$"Measure\ Threshold\ Value :" < MTV >$

"Relationship: " <R>

$$< SE > ::= \{x \mid O_1 \cap x \in < S_\Delta, x_i >\}$$

$$< S_\Delta, x_i > ::= \{(x_i \in S_\Delta) \wedge (S_\Delta \in O_1)\}$$

$$< TE > ::= \{x \mid O_2 \cap x \in < T_\Delta, x_i >\}$$

$$< T_\Delta, x_i > ::= \{(x_i \in T_\Delta) \wedge (T_\Delta \in O_2)\}$$

$$< MTV > ::= \{(\exists SE_\Delta \leftarrow O_1) \leftrightarrow (\exists TE_\Delta \leftarrow O_2) \cap (x \mid x\ is\ a\ threshold\ value)\}$$

$$< R > ::= \{(\exists SE_\Delta \leftarrow O_1) \leftrightarrow (\exists TE_\Delta \leftarrow O_2) \cap (x \mid x\ is\ relationship\ between\ SE\ and\ TE)\}$$

$$< PRM > ::= StringPRM \mid ChildPRM \mid LabelPRM \mid PropertyPRM \mid OverlapPRM \mid CustomizedPRM \mid SynonymPRM \mid PolysemousPRM$$

$$< LogicGM > ::= < Logic1 > < Logic2 > \cdots < LogicN >$$

$$< Logic1 > ::= TE \leftarrow SE$$

$$< Logic2 > ::= \{TE \cap \{\exists TE.attribute \wedge (TE.attribute \geq 1)\}\} \leftarrow SE$$

$$< Logic3 > ::= TE \leftarrow \{SE \cap \{\exists SE.attribute \wedge (SE.attribute \geq 1)\}\}$$

$$< Logic4 > ::= \{TE \cap \{\exists TEChild \subseteq TE \wedge (TEChild \geq 1)\}\} \leftarrow SE$$

$$< Logic5 > ::= TE \leftarrow \{SE \cap \{\exists SEChild \subseteq SE \wedge (SEChild \geq 1)\}\}$$

$$< Logic6 > ::= TE \leftarrow \{SE \cap \{(\exists SEChild \subseteq SE) \vee (\exists SE.attribute)\}\}$$

$$< Logic7 > ::= \{TE \cap \{(\exists TEChild \subseteq SE) \vee (\exists TE.attribute)\}\} \leftarrow SE$$

$$< Logic8 > ::= \{TE \cap \{(\exists TEChild \subseteq SE) \vee (\exists TE.attribute)\}\} \leftarrow \{SE \cap \{(\exists SEChild \subseteq SE) \vee (\exists SE.attribute)\}\}$$

$$< Logic9 > ::= \{TE \cap \{\exists TEChild \subseteq TE \wedge (TEChild \geq 1)\}\} \leftarrow \{SE \cap \{\exists SE.attribute\}\}$$

$$< Logic10 > ::= \{TE \cap \{\exists TE.attribute \wedge (TE.attribute \geq 1)\}\} \leftarrow \{SE \cap \{\exists SEChild \subseteq SE\}\}$$

$$< Logic > ::= < LogicGM > < LogicCM >$$

The constructs <*CM*> and <*LogicCM*> are related with the customized mappings and are not covered in the scope of this paper therefore its BNF are not presented. The rules in <*LogicCM*> are the same as that in the <*LogicGM*> construct. The detailed description of the ontology alignment design pattern called PRM's are elaborated in the proceeding sections.

4. MBO Design Patterns

MBO utilizes Strategy Design Pattern and Mediator Pattern to incorporate object oriented design approach for agility and reusability of the system. It also used PRM to define mapping representation format that can be used for easy expert verifications, format transformation, and ontology translation purposes. Fig. 2 represents class diagram that shows *MBO* Strategy Design Pattern, *MBO* Mediator Pattern and Pattern Relationship Models (PRM) as realization of the *MBO* in the SPHeRe system. *MBO* Strategy and Mediator design patterns explains the implementation view of the system design, while PRMs describes *MBO* ontology patterns as representation of the alignments. We have adopted the concept of Strategy and Mediator design patterns from the object oriented design community and proposed PRM in this research by interrelating them for extendible, flexible and agile system.

4.1. MBO Implementation View

4.1.1. MBO Strategy Design Pattern

Motivation: *MBO* is based on classes that differ only in their behavior, therefore algorithms needs to be isolated to provide the ability to select different algorithms at runtime.

Intent: Define a family of algorithms, encapsulate each one, and make them interchangeable. *MBOStrategy* lets the algorithm vary independently from clients that use it.

Applicability:

MBOStrategy - an interface that defines the behavior of a *MediationBridgeOntology*.

Concrete Strategies: *ChildPattern, PropertyPattern, StringPattern, SynonymPattern, PolysemyPattern, OverlapPattern, LabelPattern*; each of these pattern classes calls specific PRM for execution and then populate that information in the *MediationBridgeOntology*.

MediationBridgeOntology - This class is the context class that gets alignments information from each pattern and store it in specified format.

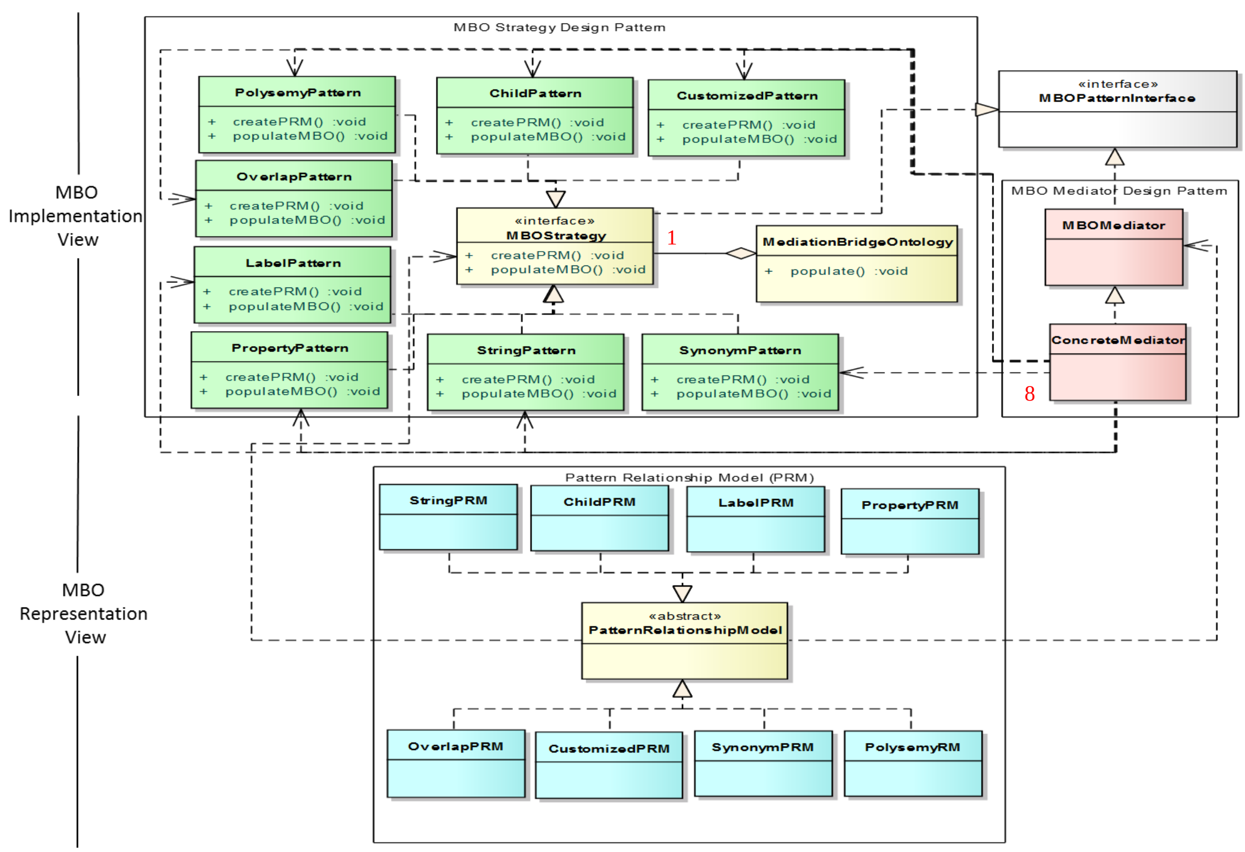


Figure 2: MBO Design Patterns Oriented Implementation and Representation Views.

4.1.2. MBO Mediation Design Pattern

Motivation: *MBO* also provides classes that can use the services of other classes, therefore mediation is necessary between classes for reusability purpose.

Intent: Define an interface for communicating with related objects for understanding interdependencies among them. *MBOMediator* provides that interface to other objects for communicating with related objects.

Applicability:

MBOMediator - An interface class used for communicating with other objects in well-defined and complex ways.

ConcreteMediator - This class keeps reference of all the colleague objects and is used to transfer the messages between colleague classes such as *ChildPattern, PropertyPattern, StringPattern, SynonymPattern, PolysemyPattern, OverlapPattern, LabelPattern*.

4.2. MBO Representation View (Pattern Relationship Model (PRM))

Each pattern class in the Strategy Design Pattern uses particular PRM class e.g. *StringPattern* class invokes *StringPRM* class for execution. All the PRM classes are derived from *PatternRelationshipModel* abstract class. Medical ontologies are used for matching purposes and performing experiments, therefore, medical standards are used as scenarios for understanding these PRMs. These PRMs realization is shown with Virtual Medical Record (vMR) and HL7 Clinical Document Architecture (CDA) standards ontologies. Both of the standards are based on the HL7 Reference Information Model (RIM) [27] that is the root of all the information models and consists of backbone classes, and their specialization and structural attributes for further defining the roles of the classes. HL7 CDA follows a CDA Refined Message Information Model (RMIM) [28] that contains information about document creation and manipulation. VMR is a data model for representing clinical data relevant to CDS by recording patient's demographics and clinical history data [29]. The generic pattern structure followed by its realization in vMR and CDA standard ontologies is described in this section. Some of these PRMs (OverlapPRM contents are also included in our paper [30], we only changed the structure of the text based on the design pattern template) are explained in object oriented design template as follows:

4.2.1. Overlap PRM

Motivation: OverlapPRM deals with the type of alignment patterns where source ontology concept with its mandatory attributes and values is mapped with target ontology concept.

Intent: Define a mechanism to transform source and target concepts by taking into account mandatory attributes as well. The mapping representation targets *Overlap Bridge* of *MBO*.

Implementation: The pattern for Overlap Bridge is shown in Fig. 3. *OverlapBridge* class has relationship with *Standard1Class* and *Standard2Class* through *hasSourceClass* and *hasTargetClass* object properties respectively. *OverlapBridge* class is related with *Match* class using *hasRelationship* object property with individuals *Exact* or *Subsume*. There are cases in which mandatory properties of both the standards are exactly matched while in some cased source concept has subsumption relationship with target concept. *Standard1Class* and *Standard2Class* are also related with each other using *hasSameRelationship* object property. *Standard1Class* consists of *MandatoryAttribute* connected by *consistMandatoryAttributes* object property and these *MandatoryAttribute* contains some values represented by *hasValue* data type property. The realization of this pattern is given in Fig. 4.

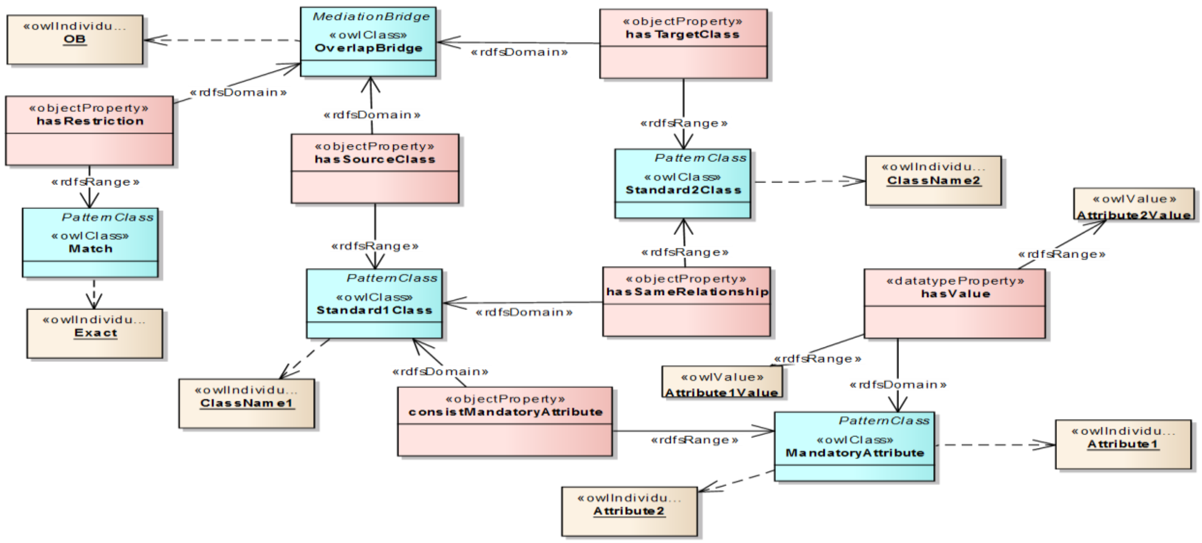


Figure 3: Overlap PRM [30].

Applicability:

HL7 CDA consists of classes in the form of triplet "class-attribute-value". Therefore, while transformation of concepts between vMR and CDA the mandatory attributes transformation is necessary for correct parsing of the document. Overlap PRM deals with such type of patterns where source standard concept with its mandatory attributes and values is converted into target concept. In this type of pattern an ontology O_i consist of class C_i with mandatory attributes MA_i having values V_i is mapped with class C_j of another ontology O_j.

We explain *OverlapPRM* with *EntryRelationship* concept of CDA standard and *RelatedClinicalStatement* concept of vMR standard as shown in Fig. 4. *EntryRelationship* class of HL7 CDA has mandatory attributes such as *typeCode* and *contextConductionInd* with values *CAUS* and *true* respectively. This information is mapped with *RelatedClinicalStatement* class of vMR, therefore translation of *RelatedClinicalStatement* class is performed with *EntryRelationship* class and its mandatory attributes and values.

```
<rdf:RDF
 xmlns:vmr="http://www.owl-ontologies.com/VMR.owl#"
 xmlns:cda="http://www.owl-ontologies.com/CDA.owl#">
 <owl:Ontology rdf:about="BridgeOntology"/>
 <!-- Defining Classes for OverlapPRM -->
  <owl:Class rdf:ID="OverlapBridge"/>
  <owl:Class rdf:ID="MandatoryAttribute"/>
  <owl:Class rdf:ID="Match"/>
  <owl:Class rdf:ID="Standard1Class"/>
  <owl:Class rdf:ID="Standard2Class"/>
 <!-- Object Properties -->
   <owl:ObjectProperty rdf:ID="consistMandatoryAttributes">
    <rdfs:domain rdf:resource="#Standard1Class"/>
    <rdfs:range rdf:resource="#MandatoryAttribute"/>
   </owl:ObjectProperty>
   <owl:ObjectProperty rdf:ID="hasRelationship">
    <rdfs:domain rdf:resource="#OverlapBridge"/>
    <rdfs:range rdf:resource="#Match"/>
   </owl:ObjectProperty>
   <owl:ObjectProperty rdf:ID="hasSameRelationship">
    <rdfs:domain rdf:resource="#Standard1Class"/>
    <rdfs:range rdf:resource="#Standard2Class"/>
   </owl:ObjectProperty>
   <owl:ObjectProperty rdf:ID="hasSourceClass">
    <rdfs:domain rdf:resource="#OverlapBridge"/>
    <rdfs:range rdf:resource="#Standard1Class"/>
   </owl:ObjectProperty>
   <owl:ObjectProperty rdf:ID="hasTargetClass">
      <rdfs:domain rdf:resource="#OverlapBridge"/>
      <rdfs:range rdf:resource="#Standard2Class"/>
   </owl:ObjectProperty>
<!-- CDA Class with its mandatory attributes and values -->
   <Standard1Class rdf:ID="CDA_EntryRelationship">
    <hasSameRelationship rdf:resource=
    "#RelatedClinicalStatement"/>
    <consistMandatoryAttributes rdf:resource="#TypeCode"/>
    <consistMandatoryAttributes rdf:resource=
    "#ContextConductionInd"/>
   </Standard1Class>
   <owl:DatatypeProperty rdf:ID="hasValue">
    <rdfs:domain rdf:resource="#MandatoryAttribute"/>
    <rdfs:range rdf:resource="&xsd;string"/>
   </owl:DatatypeProperty>
   <MandatoryAttributes rdf:ID="ContextConductionInd">
    <hasValue rdf:datatype="&xsd;string">true</hasValue>
   </MandatoryAttributes>
   <MandatoryAttributes rdf:ID="TypeCode">
    <hasValue rdf:datatype="&xsd;string">CAUS</hasValue>
   </MandatoryAttributes>
   <Match rdf:ID="Exact"/>
 <!-- VMR Class -->
   <Standard2Class rdf:ID="VMR_RelatedClinicalStatement"/>
 <!-- Overlap Bridge Relationship -->
   <OverlapBridge rdf:ID="OverlapBridgeInd">
    <hasSourceClass rdf:resource="#EntryRelationship"/>
    <hasRelationship rdf:resource="#Exact"/>
    <hasTargetClass rdf:resource="#RelatedClinicalStatement"/>
   </OverlapBridge>
</rdf:RDF>
```

Figure 4: Overlap PRM Example (CDA and vMR) [30].

4.2.2. Property PRM

Motivation: PropertyPRM deals with the type of alignment patterns where properties of the source ontology concept matches with the properties of the target ontology concept.

Intent: Define a mechanism to compare properties of source and target concepts and represent them as alignment if particular threshold is reached. This pattern reflects the mappings for *Property Based Structural Bridge (PBSB).*

Implementation: Fig. 5 shows property match pattern for PBSB class in the *MBO*. Three main classes *PropertyBasedStrcuturalBridge*, *MappedClass* and *Match* are related to each other by object properties *hasParticipatingClass*, *hasProperty* and *hasPropertyRestriction*. Each individual of PBSB class is related with *MappedClass* individuals from different standards by *hasParticipatingClass* object property. Each individual of *MappedClass* consists of properties in the form of *OWL:Class* related by *hasProperty* object property. These properties should be having exact or subsumes relationship with each other. Therefore, PBSB class individual is related with any of the *Match* class individuals using *hasPropertyRestriction* object property. This information identifies the nature of relationship between the matched classes.

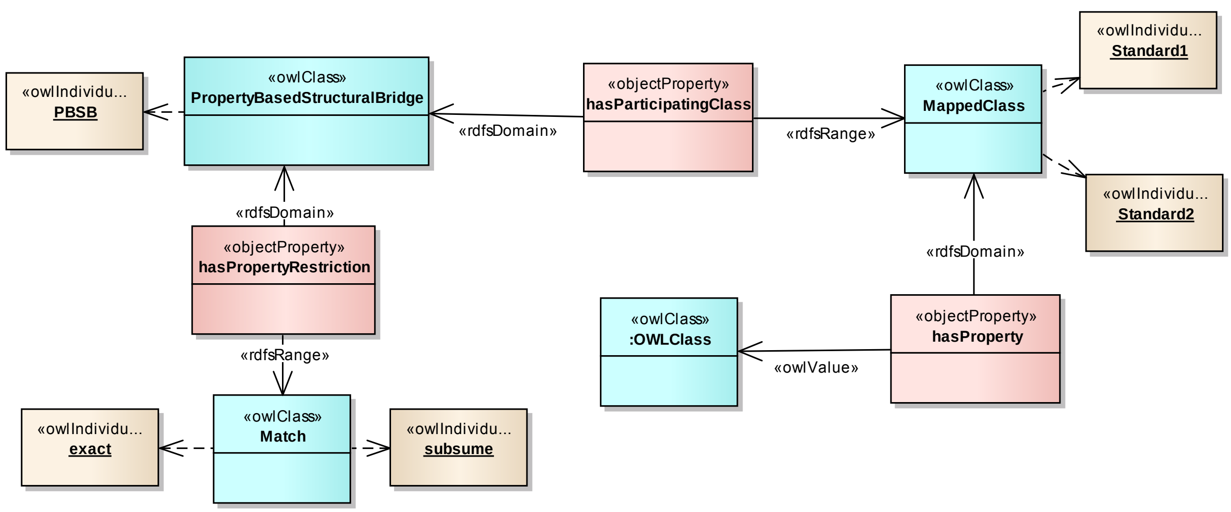


Figure 5: Property PRM.

Applicability: An instantiation example for *PropertyPRM* is described in Fig. 6. *Observation* class of CDA standard is equivalent to *ObservationResult* class of vMR standard based on their matching properties using *PropertyPRM*. *Observation* class has *Code*, *EffectiveTime*, and *Value* as its properties and *ObservationResult* class has *ObservationFocus*, *ObservationEventTime*, *ObservationValue* properties. Observation's class property *Code* is related with *ObservationFocus* property of *ObservationResult* class using *LabelPRM* and categorized under *Label Bridge*. In the same way, *EffectiveTime* and *Value* properties of *Observation* class are related to *ObservationEventTime* and *ObservationValue* properties of vMR class respectively. *SynonymPRM* that categorizes mapping information under *Synonym Bridge* is used for *EffectiveTime* and *ObservationEventTime* properties, while *StringPRM* is used for *Value* and *ObservationValue* matching by categorizing it under *String Matching Bridge*.

```xml
<rdf:RDF
 xmlns:vmr="http://www.owl-ontologies.com/VMR.owl#"
 xmlns:cda="http://www.owl-ontologies.com/CDA.owl#">
 <owl:Ontology rdf:about="BridgeOntology"/>
 <!-- Defining Classes for Property Match Pattern -->
 <owl:Class rdf:ID="PBSB"/>
 <owl:Class rdf:ID="MappedClass"/>
 <owl:Class rdf:ID="Match"/>
 <!-- Properties of Observation Class in CDA -->
 <owl:Class rdf:about="&cda;Code"/>
 <owl:Class rdf:about="&cda;EffectiveTime"/>
 <owl:Class rdf:about="&cda;Value"/>
 <!-- Observation Class associated with its properties -->
 <MappedClass rdf:ID="CDA_Observation">
  <hasProperty rdf:resource="&cda;Code"/>
  <hasProperty rdf:resource="&cda;EffectiveTime"/>
  <hasProperty rdf:resource="&cda;Value"/>
 </MappedClass>
 <!-- Properties of ObservationResult class in VMR -->
 <owl:Class rdf:about="&vmr;ObservationEventTime"/>
 <owl:Class rdf:about="&vmr;ObservationFocus"/>
 <owl:Class rdf:about="&vmr;ObservationValue"/>
 <!-- ObservationResult class associated with its properties -->
 <MappedClass rdf:ID="VMR_ObservationResult">
  <hasProperty rdf:resource="&vmr;ObservationFocus"/>
  <hasProperty rdf:resource="&vmr;ObservationEventTime"/>
  <hasProperty rdf:resource="&vmr;ObservationValue"/>
 </MappedClass>
 <!-- Indiviual of Match class -->
 <Match rdf:ID="exact"/>
 <!-- Indiviual of PBSB class -->
 <PBSB rdf:ID="PBSB_INS_CDA_VMR">
  <hasPropertyRestricvtion rdf:resource="#exact"/>
  <hasParticipatingClass rdf:resource="#CDA_Observation"/>
  <hasParticipatingClass rdf:resource="#VMR_ObservationResult"/>
 </PBSB>
 <!-- Relationship between PBSB and MappedClass -->
 <owl:ObjectProperty rdf:ID="hasParticipatingClass">
  <rdfs:domain rdf:resource="#PBSB"/>
  <rdfs:range rdf:resource="#MappedClass"/>
 </owl:ObjectProperty>
 <!-- Relationship between MappedClass and OWL:Class -->
 <owl:ObjectProperty rdf:ID="hasProperty">
  <rdfs:domain rdf:resource="#MappedClass"/>
  <rdfs:range rdf:resource="&owl;Class"/>
 </owl:ObjectProperty>
 <!-- Relationship between PBSB and Match class -->
 <owl:ObjectProperty rdf:ID="hasPropertyRestricvtion">
  <rdfs:domain rdf:resource="#PBSB"/>
  <rdfs:range rdf:resource="#Match"/>
 </owl:ObjectProperty>
</rdf:RDF>
```

Figure 6: Example: Observation (CDA) and ObservationResult (vMR) Property Match Pattern.

4.3. Parameters for analysing Design Patterns Quality

The proposed system utilized the pattern design approach by integrating object oriented design patterns with our proposed ontology alignment design patterns. This delivers solution for satisfying functional, non-functional, and alignment representation requirements of an ontology matching system. Hsueh et al. [31] provides the motivation of adopting part of their object oriented design patterns quality measure and use their tuple as $< I_F, I_N, Q>$:

- I_F: Functional Requirement Intent defines the functionality of the design pattern. For example, CBSB and PBSB bridge algorithms have intent to match source and target ontologies concepts based on their children and properties match respectively.
- I_N: Non-functional Requirement Intent describes the level of attainment of quality attributes. For example, extendibility and reusability in *MBO* case.
- Q: Quality Focus explains the quality focus between I_F and I_N.

We are using Strategy and Mediator design patterns that offer reusability and extendibility metrics to our system and provide assistance to ontology alignment PRM with the tuple as $<S,T,A,EC,MV>$:

- S: Source Concept that belongs to the matching source ontology.
- T: Target Concept that belongs to the matching target ontology.
- A: Attribute is supported by the evaluation criteria for matching and is divided into simple or composite attributes. A simple attribute performs matching with single evaluation criteria while composite includes multiple evaluation criteria combines on a single platform.
- EC: Evaluation Criteria defines the purpose of the alignment generation between concepts. Each bridge algorithm has particular evaluation criteria to achieve objective.
- MV: Matching Value decides about the fulfilment of the evaluation criteria.

The quality focus of the proposed system is on decrease coupling and increase polymorphism to achieve extendibility and reusability, described in detail in Section 6.4.

5. Methodology

Our proposed *MBO* is part of the ontology matching system we developed called SPHeRe [9]. SPHeRe system is based on different bridge algorithms that are represented in a mapping representation format provided by the *MBO*. Accuracy and performance are the two factors that helps in achieving the goals, and these are accomplished by *Matcher Library* and

Parallel Matching Framework of SPHeRe working model as shown in Fig. 7. The definitions of the concepts used in the proposed architecture are described in Table 3.

Table 3: Concepts and Definitions

Concept	Definition
SPHeRe Execution Control	It manages the communication with external and internal entities. It is responsible for ontology loading (source and target ontologies) and providing information about execution of bridge algorithms in the Matcher Library to Parallel Matching Framework for parallel execution of the algorithms.
Parallel Matching Framework	It support parallel execution of matching bridge algorithms over mutli-core and multi-node computational resources. The performance of the system is handled by this custom high performance computing framework.
Matcher Library	It consists of the bridge algorithms that are invoked for performing the matching tasks. Each bridge algorithm generates mappings that are stored and represented in the *MBO*.
Distributor	It is responsible for the division of matching jobs over parallel hardware depending upon their computational ability.
Parallel Hardware Interface	It is used by *Distributor* to exploit the multiple cores available over commodity hardware for parallelism.
Aggregator	It accumulates the respective results of all matching jobs from all computing nodes after the completion of parallel matching.

SPHeRe Execution Control manages the communication with external and internal entities. It is responsible for ontology loading and providing information about execution of bridge algorithms in the *Matcher Library* to *Parallel Matching Framework* for parallel execution of the algorithms. *Matcher Library* consists of bridge algorithms such as *String Matching Bridge*, *Synonym Bridge*, *Label Bridge*, *Overlap Bridge*, *Customized Bridge*, *CBSB*, *PBSB*, *and Polysemous Bridge.*

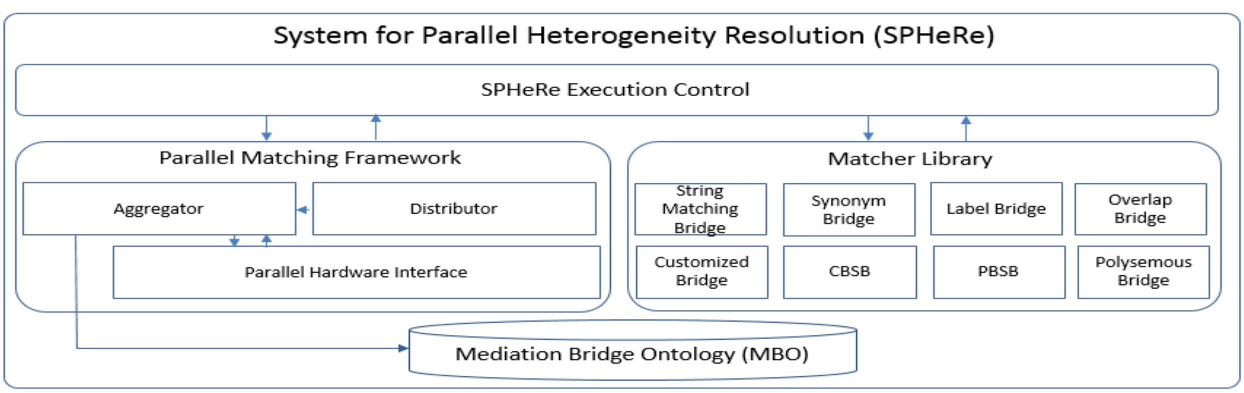


Figure 7: SPHeRe Working Model.

Ontology matching being a computationally intensive problem require adequate computational resources for effective resolution in acceptable time. To generate mappings with performance in perspective, we have implemented a custom high performance framework, *Parallel Matching Framework*, to support parallel execution of matching algorithms over mutli-core and multi-node computational resources. To accomplish parallel matching we have implemented two core components i.e., *Distributor* and *Aggregator*. *Distributor* is responsible for the division of matching jobs over parallel hardware depending upon their computational ability. *Parallel Hardware Interface* is used by *Distributor* to exploit the multiple cores available over commodity hardware for parallelism. After the completion of parallel matching, *Aggregator* component, accumulates the respective results of all matching jobs from all computing nodes. This accumulated result is formalized by *Mediation Bridge Ontology*, to be further utilized as an alignment. The generated bridge ontology is also persisted in the repository for future utilization.

The process of SPHeRe working model is described in Figure 8. Initially, source and target ontologies are loaded for matching process. Both the ontologies are parsed based on the ontology constructs such as classes, properties, annotations, and relationships. Distributor access the primary algorithms initially that includes the String Matching, Label, and CBSB bridge algorithms as some of their attributes are common. Based on these, ontology constructs are accessed and assigned to the cores for processing. Each core is assigned a specific task to perform in parallel for a particular bridge algorithm and the output is provided to the Aggregator to generate the *MBO*. In the same way, other algorithms are executed for the generation of mappings and their storage in *MBO*. Further details of this process working in parallel environment are available in [9].

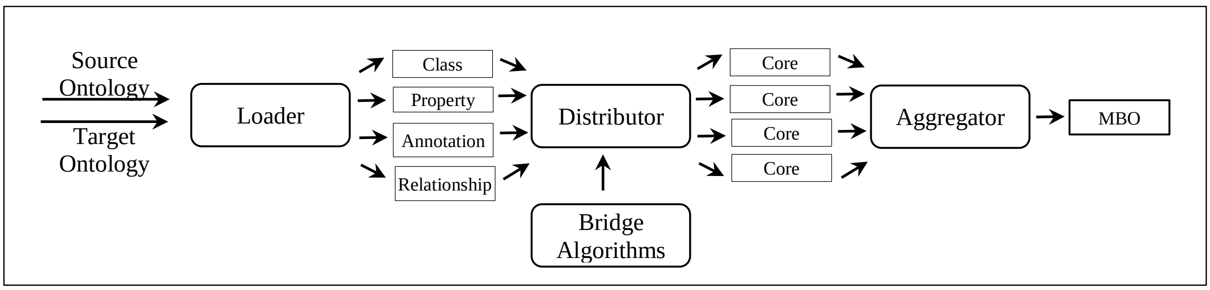


Figure 8: Process Workflow

6. Evaluation

Existing ontology matching systems mainly focus on the accuracy of mappings and lack assessment of the external quality factors from the measurement of the internal design properties. We evaluate our proposed system with Coupling Factor (COF), Number of Polymorphic methods (NOP), and Rate of Change (RoC) metrics by comparing it with existing systems, FALCON and LogMap. We selected FALCON and LogMap for comparison with the proposed system because of factors such as; participation in OAEI several years, corresponding publications availability to understand their approach thoroughly, its source code availability (to understand the design and implementation of the system), and also complete system availability (to run ontology matching tests for observing its output). These systems class diagrams are generated from their source code using Intellij Idea tool[5], that support a wide array of refactoring for Java, cross language refactoring and other advanced features [32]. We use Quality Model (QMOOD) approach [10] to quantitatively assess the external factors such as extendibility and reusability as measures of software maintainability.

6.1. Coupling Factor (COF)

Coupling Factor (COF) is a metric to determine dependencies between the classes. Therefore, the formula to calculate COF is given in Equation 1.

$$COF = \frac{df}{tc^2 - tc} \quad (1)$$

where *df* = Total Dependency Factor
and *tc* = Total No. of Classes

SPHeRe system is based on the *MBO* using object oriented and ontology design patterns. Therefore, COF value of SPHeRe is less as compare to FALCON and LogMap systems. Fig. 2 shows the *df* and *tc* of the proposed system and the COF_{SPHeRe} is calculated as shown in Equation 2.

$$COF_{SPHeRe} = \frac{9}{12^2 - 12} = 0.068 \quad (2)$$

We compared our system with FALCON ontology matching system and used its Matcher package to calculate COF of its different sub-packages as shown in Fig. 8(a). We observed that FALCON has high coupling as compare to the proposed system. Class diagram of FALCON system's Package PBM is shown in Fig. 8(b) and Equation 3 calculates its COF value as 0.127, which is very high as compare to proposed system.

$$COF_{FALCON_{PackagePBM}} = \frac{14}{11^2-11} = 0.127 \tag{3}$$

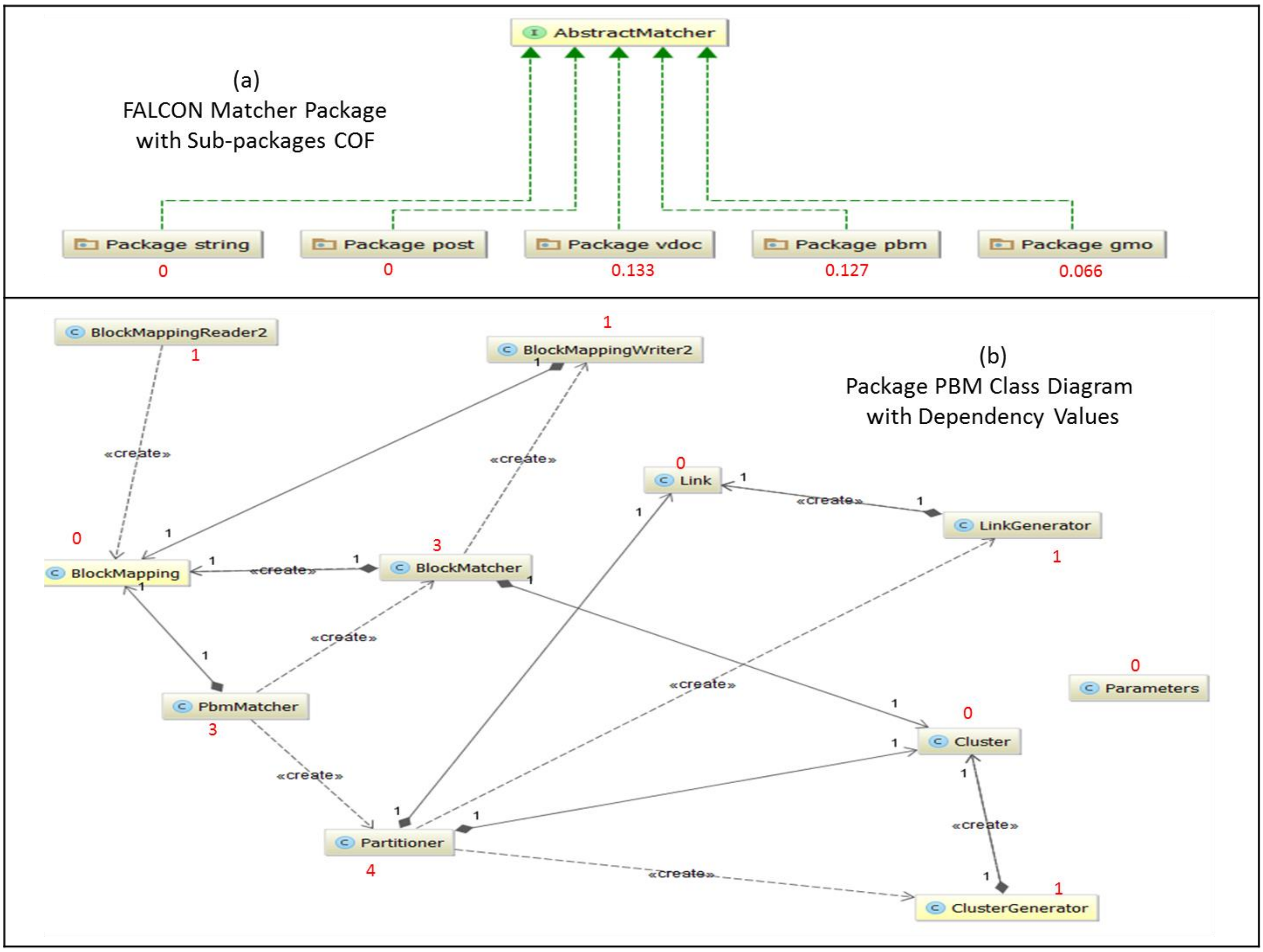


Figure 9: FALCON Packages and Coupling Factor

LogMap system overall class diagram consists of approximately 26 packages and classes having too much dependencies with each other, resulting in highly coupled system. We selected two packages (Stemming and Reasoning) for comparison with the proposed system. These packages class diagrams are shown in Fig. 9. Fig. 9 (a) and (b) illustrates class diagrams of LogMap system's Stemming and Reasoning packages respectively. Stemming package has more COF as compare to proposed system while Reasoning package has less COF value as shown in Equation 4 and 5 respectively.

$$COF_{LogMap_{PackageStemming}} = \frac{20}{14^2-14} = 0.11 \tag{4}$$

$$COF_{LogMap_{PackageReasoning}} = \frac{13}{17^2-17} = 0.047 \tag{5}$$

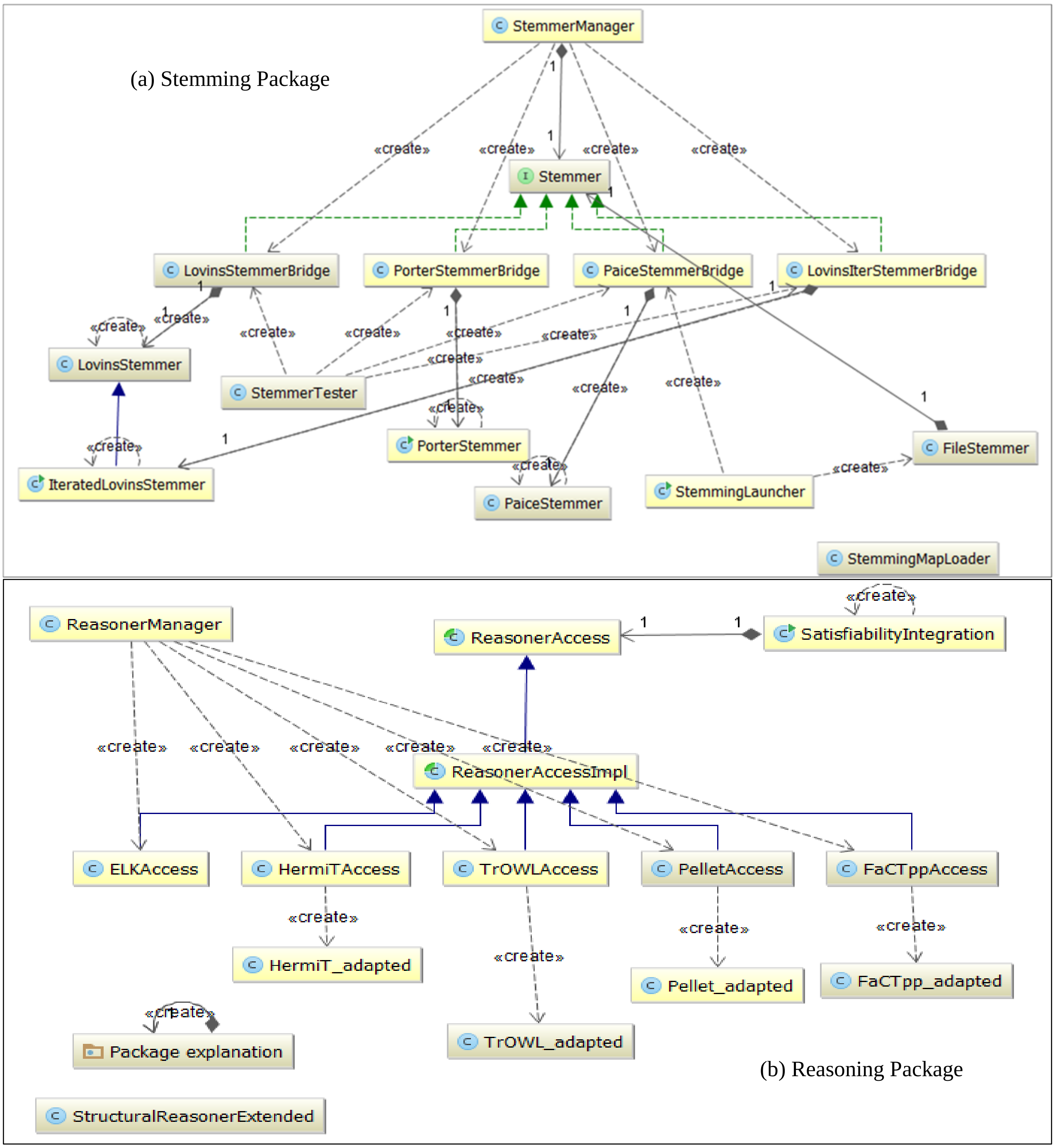


Figure 10: LogMap Class Diagrams: (a) Stemming Package, (b) Reasoning Package.

6.2. Number of Polymorphic Methods (NOP)

The number of polymorphic methods (NOP) in a class diagram determines the value for polymorphism. Therefore, in Fig. 2, it can be observed that *populateMBO()* is the polymorphic method that returns *MBOStrategy* instance. So, the NOP in a class diagram is the level of polymorphism which is 7 in the proposed system as shown in Equation 6. This suggests that the system has more extendibility by implementing only the *populateMBO()* polymorphic method.

$$NOP_{SPHeRe} = 7 \quad (6)$$

The increase in composition and association of a class diagram results in high coupling and less polymorphism. FALCON class diagram shows more composition and association relationships whereas the proposed system contains more polymorphic methods in the class diagram. Fig. 8(a) shows extend relationship to *AbstractMatcher* class, which suggests that there may be a polymorphic method in class diagram of FALCON system's Package PBM, shown in Fig. 8(b). Therefore, maximum polymorphism value for FALCON system is 1 as shown in Equation 7, which is less as compare to the proposed system. A new bridge algorithm must have to implement *populateMBO()* polymorphic method, thus increasing the polymorphism value. LogMap system two packages polymorphism value is 5 as shown in Equation 8, which is also less than the proposed system.

$$NOP_{FALCON} = 1 \quad (7)$$

$$NOP_{LogMap} = 5 \quad (8)$$

6.3. Rate of Change (RoC)

The key factor for successful ontology matching system is flexibility and extendibility based on new requirements. As new techniques and methodologies continuously evolve in ontology matching domain, measurement of Rate of Change (RoC) based on COF becomes necessary for evaluating the extendibility of the system. Therefore, RoC can be measured by Equation 9, based on change in the COF due to addition of new classes and dependencies.

$$RoC = \Delta COF \quad (9)$$

For testing rate of change, we introduced unidirectional dependency of +1 in *df* and *tc*, so equations 2 and 3 are transformed to equations 10 and 11 respectively. In the same way LogMap's Equations 4 and 5 are transformed to Equations 12 and 13 respectively.

$$COF_{SPHeRe'} = \frac{10}{13^2-13} = 0.064 \quad (10)$$

$$COF_{FALCON'_{PackagePBM}} = \frac{15}{12^2-12} = 0.114 \quad (11)$$

$$COF_{LogMap'_{PackageStemming}} = \frac{21}{15^2-15} = 0.1 \quad (12)$$

$$COF_{LogMap'_{PackageReasoning}} = \frac{14}{18^2-18} = 0.045 \quad (13)$$

The proposed system RoC is considerably less than FALCON and LogMap system, which shows the extendibility and reusability features of our system and easy adaptation of new changes. Equation 14 and Equation 15 shows that the proposed system has the better capacity to accommodate any changes in the system design as compare to FALCON system. LogMap's Stemming package has higher RoC while Reasoning package has less RoC value as compare to proposed system RoC value. These packages RoC values are shown in Equations 16 and 17.

$$\Delta COF_{SPHeRe} = COF_{SPHeRe} - COF_{SPHeRe'} = 0.068 - 0.064 = 0.004 \quad (14)$$

$$\Delta COF_{FALCON_{PackagePBM}} = COF_{FALCON_{PackagePBM}} - COF_{FALCON'_{PackagePBM}} = 0.127 - 0.114 = 0.013 \quad (15)$$

$$\Delta COF_{Logmap_{PackageStemming}} = COF_{Logmap_{PackageStemming}} - COF_{Logmap'_{PackageStemming}} = 0.11 - 0.1 = 0.01 \quad (16)$$

$$\Delta COF_{Logmap_{PackageReasoning}} = COF_{Logmap_{PackageReasoning}} - COF_{Logmap'_{PackageReasoning}} = 0.047 - 0.045 = 0.002 \quad (17)$$

6.4. Discussion

Extendibility and reusability are the two main metrics for evaluation of the proposed system. These are discussed in relation to polymorphism and coupling of the proposed system measured in the previous sub-sections.

6.4.1. Extendibility

Extendibility is one of the evaluation metric of the proposed system. A new bridge algorithm can easily be accommodated in the system design with low coupling, high polymorphism and less rate of change as explained in previous section. This is achieved by using strategy design pattern with the PRMs. The new bridge algorithm only requires to implement the interface. We consider as a scenario that a new bridge is introduced that is based on instance based matching, called Instance Matching Bridge. *InstancePRM* is connected to the *PRM* in the *MBO* representation view that deals with actual representation of the alignment. A class *InstancePattern* will implement the *MBOStrategy* interface class and provide its reference information to *ConcreteMediator* class. Therefore, its tuple metrics information is as follows:

- I_F: An algorithm to match source and target concepts based on instances comparison.
- I_N: *InstancePRM* and *InstancePattern* classes to be added in the class diagram to support extendibility. This algorithm resolves specific problem and only requires to implement an interface.
- *Q*: *<polymorphism, increased>*
- *S*: Source Concept that belongs to the matching source ontology.
- *T*: Target Concept that belongs to the matching target ontology.
- *A*: Instances of source and target concepts.
- *EC*: Specific number of instances matches than source and target concepts are similar. A threshold value *n* should be achieved by the number of instance matched.
- *MV*: A value between 0 and 1 that is based on instances matched.

6.4.2. Reusability

New bridge algorithm can be added to the system that can utilize existing bridge algorithms. Mediation between new and existing bridges is performed using mediator design pattern and PRMs. For example, a new bridge called Hyponym Bridge is introduced that uses CBSB and PBSB together to find matching concepts. *HyponymPRM* is connected to *PRM* in *MBO* representation view, and *HyponymPattern* class is also introduced to implement *MBOStrategy* interface class and provide reference to *ConcreteMediator* class. Tuple information is as follows:

- I_F: An algorithm to match source and target concepts based on existing CBSB and PBSB algorithms.
- I_N: *HyponymPRM* and *HyponymPattern* classes to be added in the class diagram for reusability.
- *Q*: *<coupling, decrease>*
- *S*: Source Concept that belongs to the matching source ontology.
- *T*: Target Concept that belongs to the matching target ontology.
- *A*: Children and properties match of the matching concepts.
- *EC*: A specific number of children and properties match for source and target concepts match.
- *MV*: A value between 0 and 1 that is based on CBSB and PBSB results match.

These metrics enable easy integration of new bridge algorithms into the system that prolongs the system lifetime. State of the art matching techniques and new methodologies can be plug and play to the proposed system, without disturbing the design of the system.

7. Conclusion and Future Work

Expressiveness in formal representation of alignments and use of object oriented and ontology alignment design patterns prolongs the duration of use of ontology matching systems. The proposed *MBO* approach uses Strategy and Mediator object oriented design patterns with ontology alignment design patterns, PRM to support the extendibility and reusability aspects of the SPHeRe system. Evolution in matching techniques or introduction of new bridge algorithms is made convenient by the proposed approach, and therefore possess significance of adoption by the ontology matching community.

Effectiveness of the alignments stored in the *MBO* can be measured by evaluating a case study for transformation process between two ontologies of the same domain. Our objective is to match two medical standard based ontologies with SPHeRe, store the alignments in the *MBO*, and finally use those alignments for transformation from one medical standard ontology to another related to the same domain.

Notes

1. http://oaei.ontologymatching.org/.
2. http://www.oodesign.com/strategy-pattern.html.
3. http://www.oodesign.com/mediator-pattern.html.
4. http://en.wikipedia.org/wiki/Backus%E2%80%93Naur_Form
5. http://www.jetbrains.com/idea/.

Acknowledgements

This research was supported by the MSIP (Ministry of Science, ICT & Future Planning), Korea, under the ITRC (Information Technology Research Center) support program supervised by the NIPA (National IT Industry Promotion Agency)" (NIPA-2013-(H0301-13-2001)).
This work was also supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (No. 2013-067321)).
This work was also supported by the Industrial Core Technology Development Program (10049079 , Development of Mining core technology exploiting personal big data) funded by the Ministry of Trade, Industry and Energy (MOTIE, Korea)"

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