



Managing Change History in Dynamic Web Ontologies

Ph.D. Dissertation Defence
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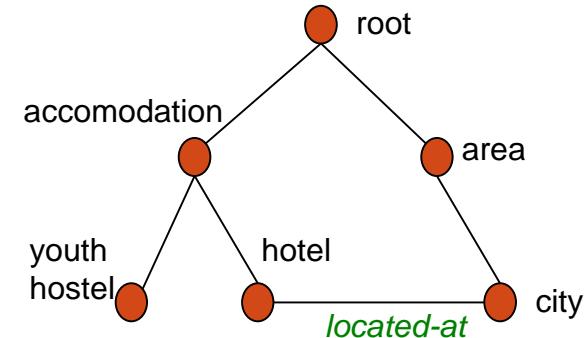
Outline

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 - Motivation and Problem Statement
 - Thesis Contributions
- Related Work
- Proposed Methodology
 - Change Representation
 - Change Logging
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- Contributions
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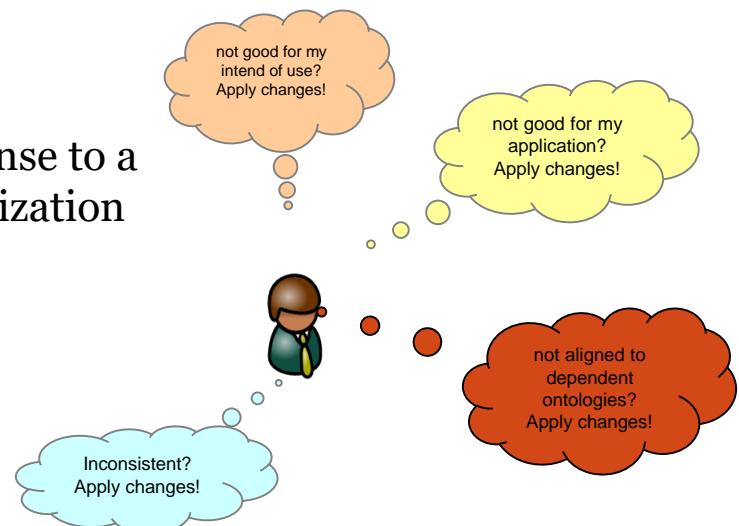
Introduction

Ontology Change Management

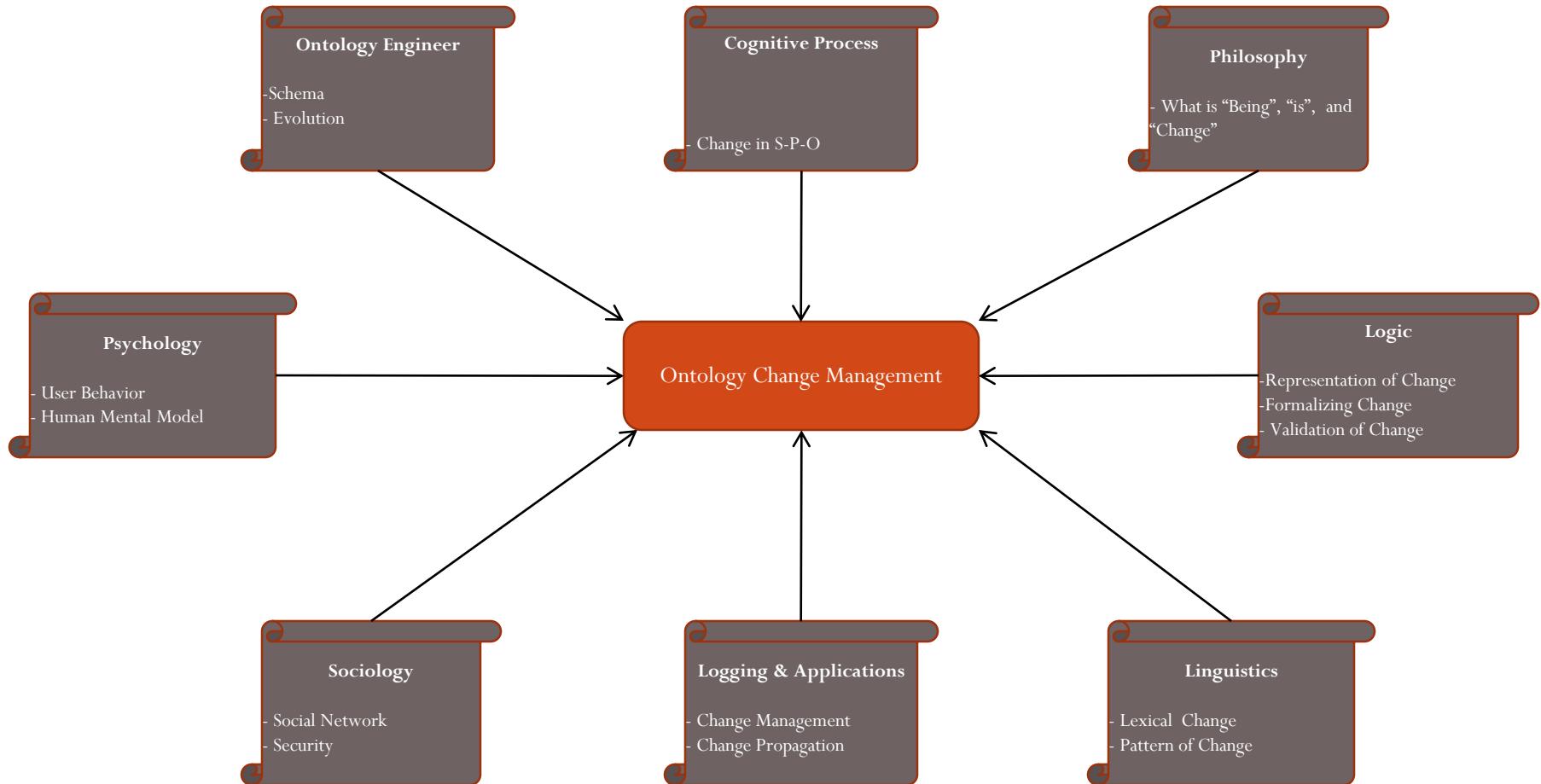
- “Ontology defines the **kind and structures** of objects, properties, events, and relations in every area of reality” [1].
 - Formal, explicit specification of a **shared conceptualization** [2]



- Ontology Evolution [3]
 - The process of modifying an ontology in response to a certain change in the domain or its conceptualization

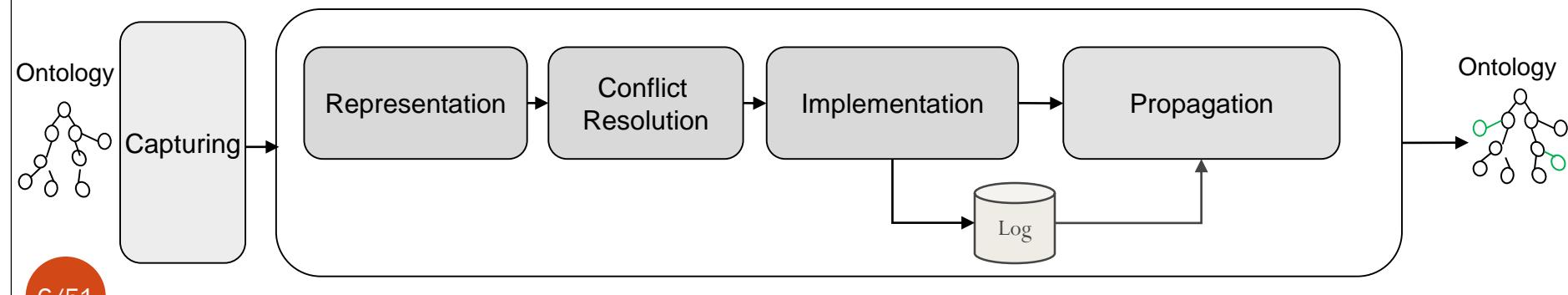


Ontology Change Management

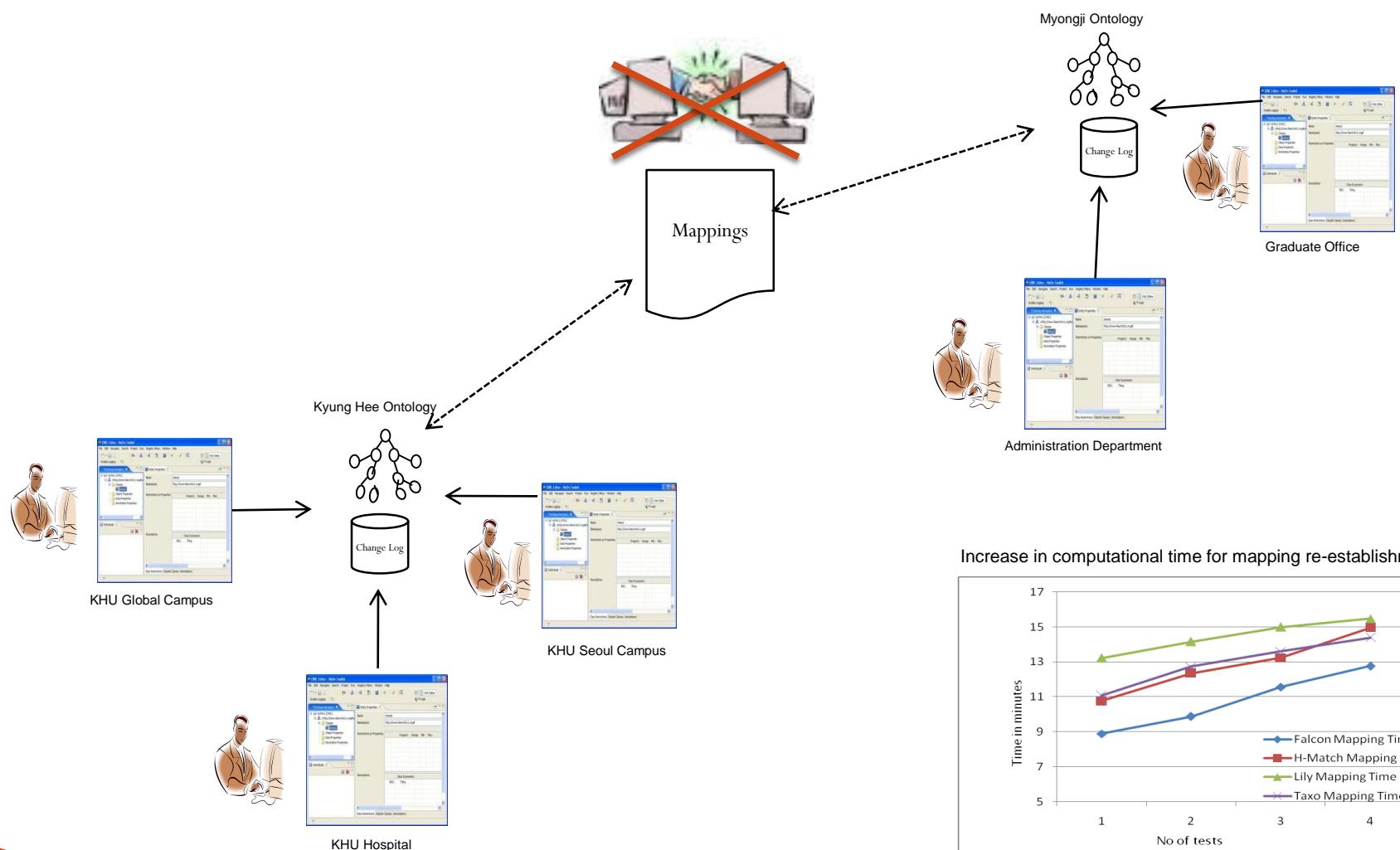


Ontology Change Management

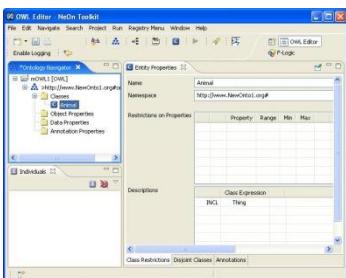
- Change Management
 - A layered approach for **Capturing**, **Representation** and **Conflict Resolution** of changes [3, 4]
 - Supports: Evolution, Versioning, Merging, Integration, and collaborative engineering [3, 5]
 - Change history **Management** and **Propagation** to dependent entities (i.e., synchronization) in the distributed environment [3, 6]



Motivation

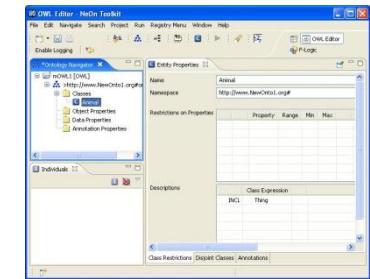
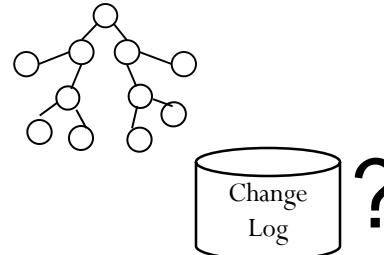


Motivation

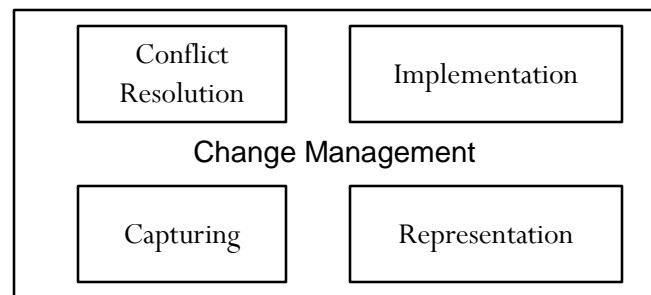


KHU Global Campus

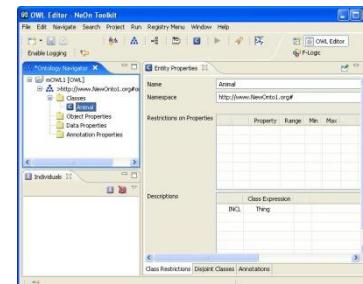
Kyung Hee Ontology



KHU Seoul Campus



KHU Hospital



Examples

- ACM and MSC Classifications
- NCI Thesaurus
- Health Ontologies
- Social Network Ontologies

Problem Statement

- No comprehensive Change History Management Framework for effective change capturing, formal representation, and logging.
- How to Reconcile stalled mappings? How to achieve a performance and memory efficient procedure with good accuracy?

Related Work

Related Work

- The increasing information on web needs proper assessment, manipulating, evolution, merging, integrating, and consistent maintenance [3, 4, 5, and 6]

Approaches	Change Capturing	Changes Representation	Conflict Resolution	Change Implementation	Change Propagation	System Working
L. Stojanovic, et al. [38].	X	✓	X	X	✓	User Dependent
M. Klein, N. Noy, et al. [5, 36, and 37]	X	✓	X	✓	✓	User Dependent
T. Gabel, et al. [35] (KAON)	X	✓	✓	✓	X	Semi Automatic
P. Plessers, et al. [10 and 34]	X	X	X	✓	X	User Dependent
D. Oberle, et al. [33]	✓	✓	✓	✓	X	User Dependent
S. Castano, et al. [32]	✓	✓	✓	X	X	Semi Automatic
F. Zablith [31]	✓	✓	X	✓	X	Towards Automatic ontology Evolution
A. Maedche [29]	✓	X	X	X	X	User Dependent
Gu [30]	X	X	✓	✓	X	User Dependent

Related Work

- Change Representation

1. Y. Sure in 2004, ontology model for change in KAON framework [7]
2. M. Klein in 2004, detailed OWL Change Ontology for distributed ontologies [5]
3. G. Flouris in 2006, a Belief Change model for KAON based on [5]
4. R. Palma in 2011, OWL 2 Ontology Change model for collaborative ontology engineering [6]

- Change Logging

1. Changes Tab [8] list ontology changes in Protégé
2. Log Ontology II [9] logs CRM Ontology changes in sequential manner
3. Version Log Generator [10] logs changes from Protégé in a ontology change model
4. OWL 2 Ontology Change [6] capture and Log ontology from NeOn Toolkit

Problems

1. Depends on the underlying ontology model
2. Granularity level for change classification
3. Strict specifications and usage

Problems

1. No correspondence among the changes of a particular session
2. No classification of versioned changes
3. Application specific usage, not generic

Related Work

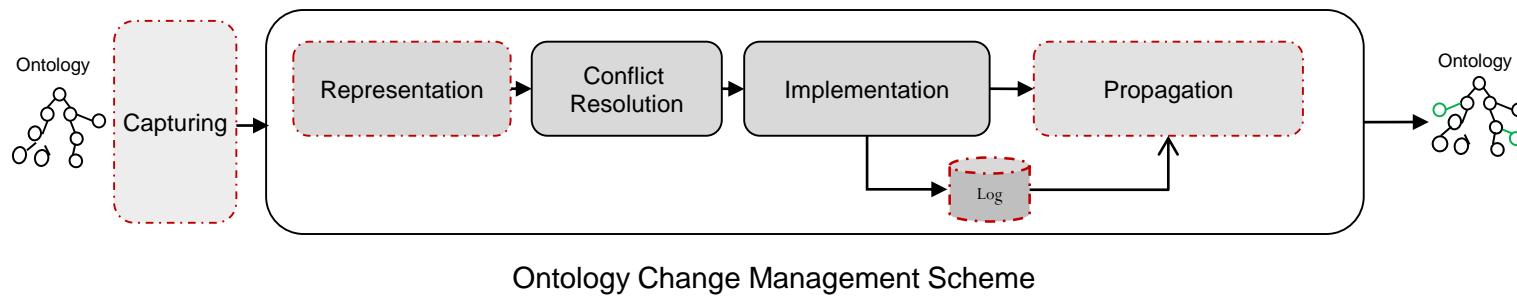
- Mapping Procedures
 - 1. Schema based incremental mappings evolution [11]
 - 1. Support Local as View and Global as View approaches
 - 2. Mapping evolution to maintain consistency [12]
 - 1. Between schema and annotations
 - 3. FOAM [13], Falcon [14], H-Match [15], Prompt [16], Lily [17], AgreementMaker [18], and TaxoMap [19] are most widely used mapping systems
 - 1. Mapping accuracy
 - 2. Time efficiency

Problems

- 1. Schema and ontology are fundamentally different
- 2. Restrict the mapping evolution
 - 1. Defined sets of mappings
- 3. No support for mapping reconciliation
- 4. Resource consuming job
 - 1. Computational time and runtime memory
- 5. No synchronization of ontology evolution (change) with mapping evolution

Limitations of Related Work

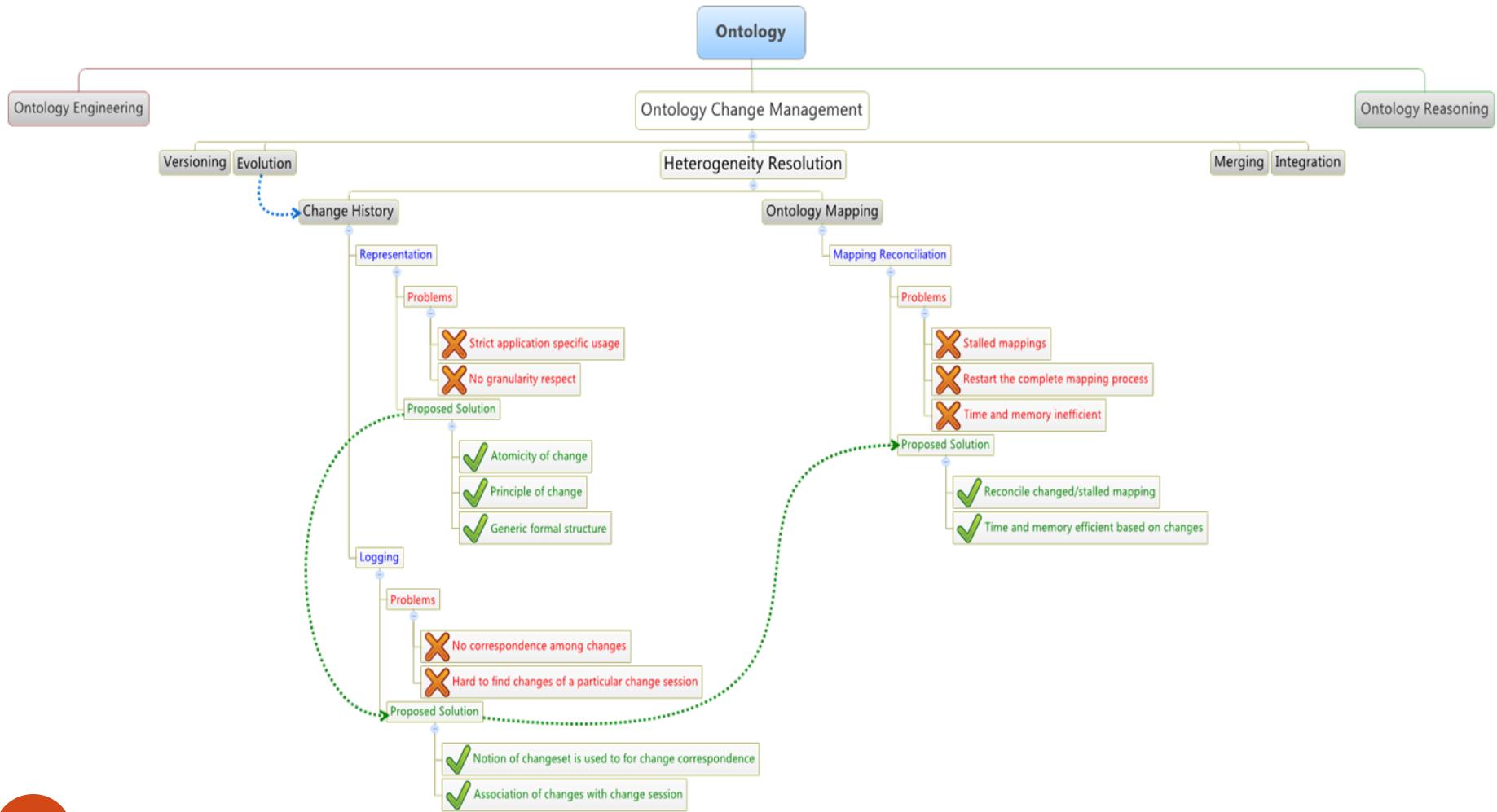
- No uniform representation of ontology changes with bases from classified granular levels
- Strict application specific usage, not generic
- No correspondence among the stored changes of a change session
- No synchronization (propagation) of ontology evolution (change) with mapping evolution
- Mapping re-establishment becomes a resource consuming job



Proposed Solutions

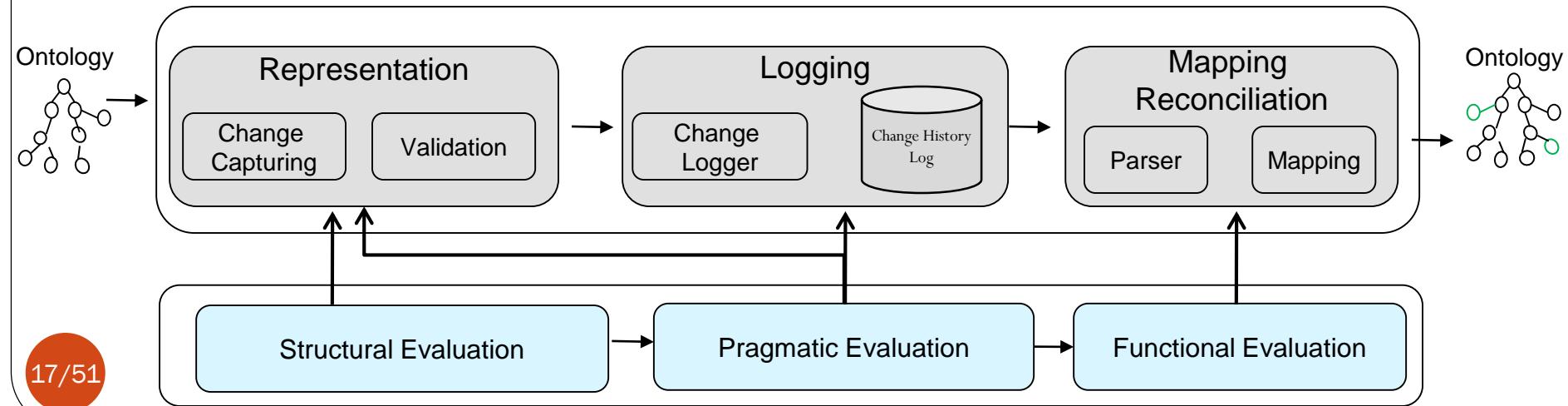
- The proposed Change History Management Framework support
 - Change Representation and Logging
 - Formal and Effective Representation
 - Accurate Change Capturing
 - Change Logging of corresponding changes
 - Mapping Reconciliation
 - With Less Time and Memory consumption
 - With good Accuracy

Summary of Proposed Idea



Workflow of Proposed Idea

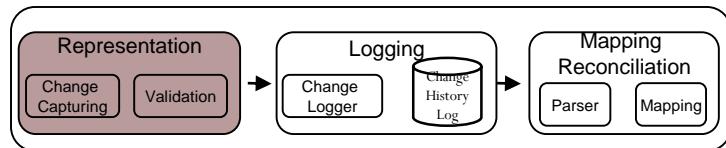
- Representation of changes in **uniform, formal, and coherent** manner
- Change history logging that support **capture, storage, and retrieve** of changes effective and efficiently
- Reconciliation of stalled mapping **in less time and memory usage**



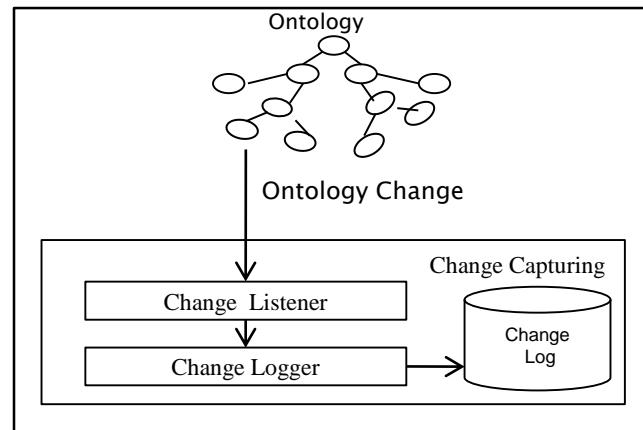
Proposed Methodology

- Asad Masood Khattak, Zeeshan Pervez, Sungyoung Lee and Young-Koo Lee, "**Intelligent Healthcare Service Provisioning using Ontology with Low Level Sensory Data**", Transaction on Internet Information Systems (TIIS) (IF: 0.164) ISSN: 1976-7277, Vol.5, No 11, pp. 2016-2034, 2011.
- Asad Masood Khattak, Zeeshan Pervez, Khalid Latif, and Sungyoung Lee, "**Change History Ontology: A Theoretical Perspective**", Journal of Advance Science Letters (IF: 1.253), ISSN:1936-6612, 2011.
- Asad Masood Khattak, Zeeshan Pervez, Wajahat Ali Khan, Sungyoung Lee and Eui-Nam John Huh, "**Automatic System for Rule Learning and Evolution**", Journal of Advance Science Letters (IF: 1.253), ISSN:1936-6612, 2012.
- Asad Masood Khattak, Zeeshan Pervez, Khalid Latif, and Sungyoung Lee, "**Time Efficient Reconciliation of Mappings in Dynamic Web Ontologies**", Journal of Knowledge-based Systems, (IF:1.574), 2012 .
- Asad Masood Khattak, Zeeshan Pervez, Khalid Latif, A. M. Jihad Sarkar, Sungyoung Lee and Young-Koo Lee, "**Reconciliation of Ontology Mappings to Support Robust Service Interoperability**", The 8th IEEE International Conference on Services Computing (IEEE SCC 2011), Washington DC, July 4-9, 2011.

Change Capturing

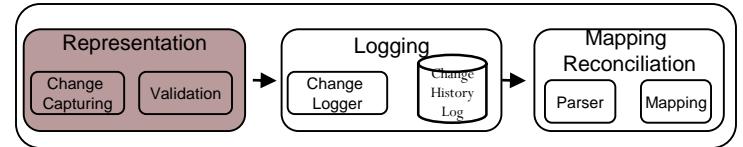


- Change Capturing
 - Change Listener
 - KnowledgeBaseListener, ClsListener, SlotListener, FacetListener, InstanceListener
 - Change Logger
 - Programming API's used are Jena, rdf-api, rdf-backend, align, arq, Protégé, Protégé-OWL.

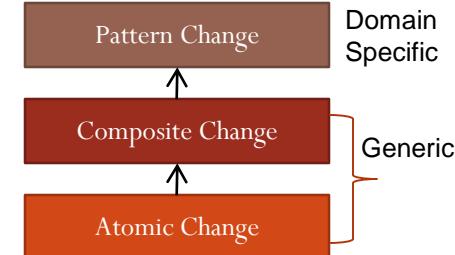


- Asad Masood Khattak, Zeeshan Pervez, Khalid Latif, and Sungyoung Lee, "Change History Ontology: A Theoretical Perspective", Journal of Advance Science Letters (IF: 1.253), ISSN:1936-6612, 2011.
- Asad Masood Khattak, Khalid Latif, Sung-young Lee, Young-Koo Lee, Manhyung Han, and Hyoung Il Kim, "Change Tracer: Tracking Changes in Web Ontologies", 21st IEEE International Conference on Tools with Artificial Intelligence (ICTAI), Newark, USA, November 2009.

Change Validation



- Ontology Change can be categorized into
 - Atomic Change**, Composite Change, Pattern Change
- Change Principle



- Minimal Change → $\text{Change} \equiv \exists x \{x | x \in \Delta, x = 1 \text{ targetChange}\}$
- Change Success → $\text{Change} \equiv \exists x \{x | x \in \Delta, \Delta = \{C_1, \dots, C_n\}\}$
where $C = \text{ChangeInstance}$
 $\text{Change} \equiv 1 \text{ targetChange} \sqcap \min.(\text{Change.Effects})$
- Change Validity → $\text{Change} \equiv \exists x \{x | x \in \Delta, \Delta = \{C_1, \dots, C_n\}\}$
where $C = \text{ChangeInstance}$
 $\text{Change} \equiv 1 \text{ targetChange} \sqcap$
 $\text{Ontology.consistent.(Change)} = \text{true}$

Representation

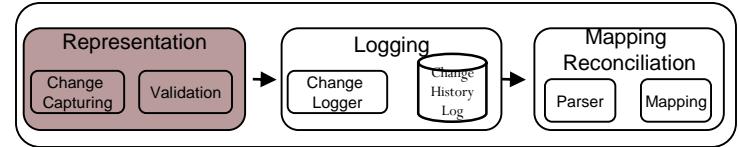
Five Aspects:

1. WHO performed the Change (**User**)
2. WHEN this change is applied (**Timestamp**)
3. HOW is the change identified in a change list (**ChangeID**)
4. WHAT is the change (**Element**)
5. WHERE the change is applied in the ontology-context (**Parameters**)

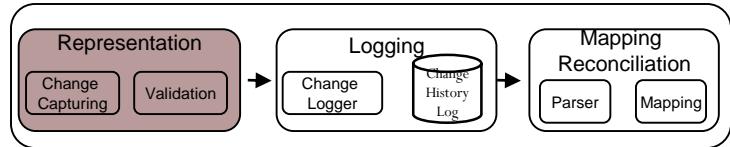
Meta Data

Change Data

Single Ontology Change

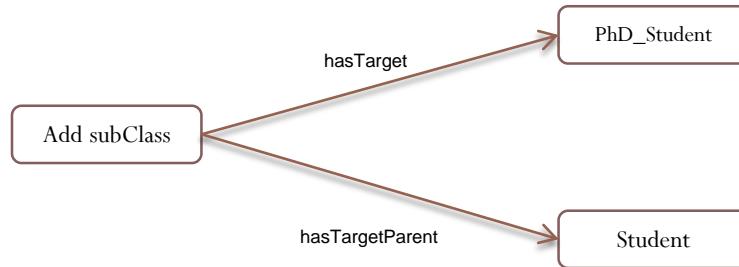


Representation

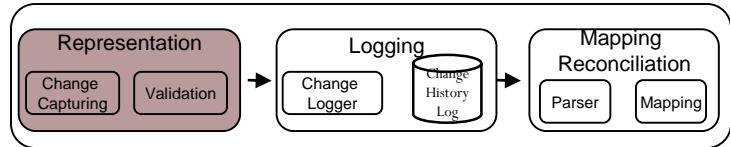


- Change representation in triple (Subject-Predicate-Object)

Asad Thu Mar 10 15:51:26 GMT 2011 1299772286625 Add subClass (PhD_Student, Student)

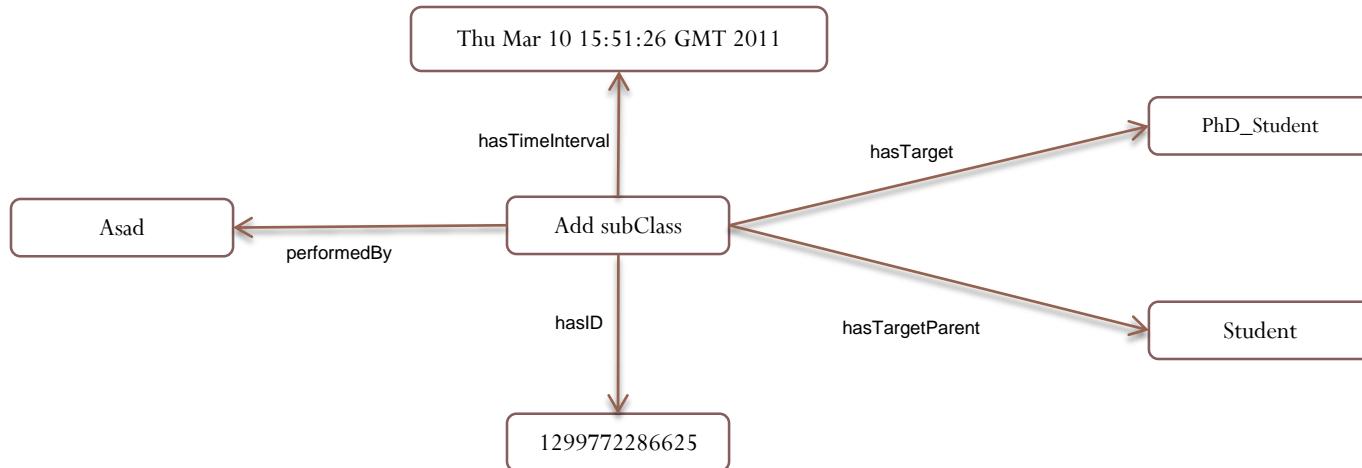


Representation

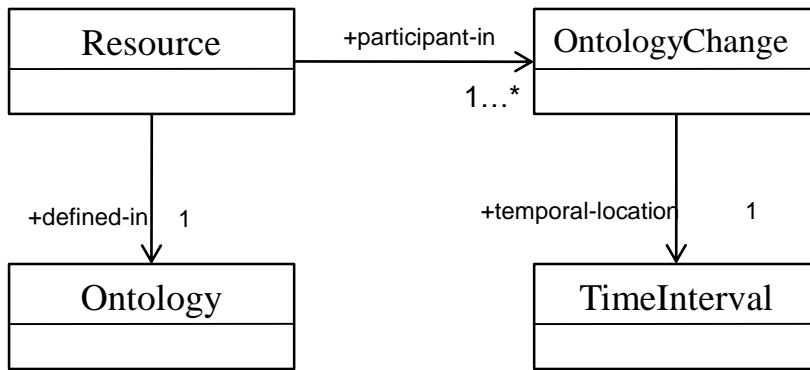
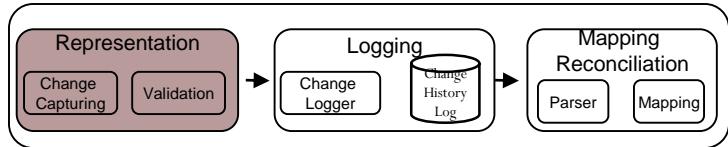


- Change representation in triple (Subject-Predicate-Object) building a semantic net of an atomic change

Asad Thu Mar 10 15:51:26 GMT 2011 1299772286625 Add subClass (PhD_Student, Student)



Representation



- Ontology Changes

Asad Thu Mar 10 15:51:26 GMT 2011 1299772286625 Add subClass (PhD_Student, Student)

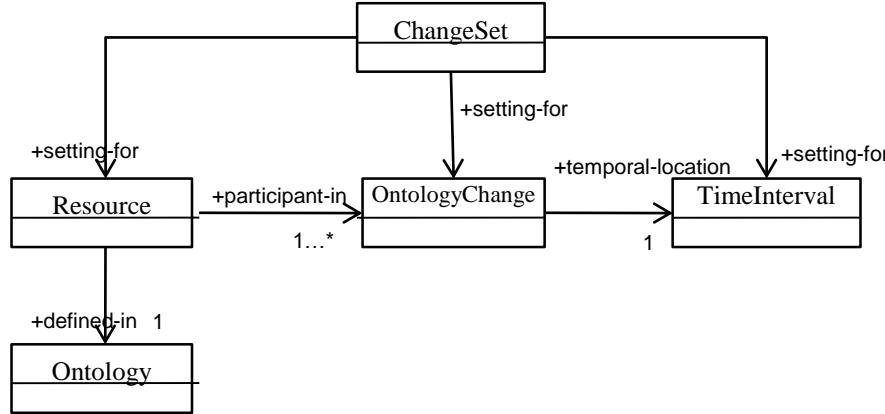
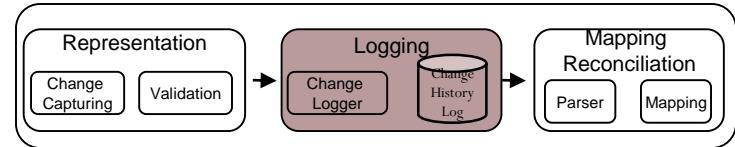
$\text{SubClassAddition} \equiv \text{ClassAddition} \sqcap \forall \text{targetSubClass}.\text{class}$
 $\sqcap = 1 \text{ targetParent}$

$\text{ClassAddition} \equiv \text{ClassChange} \sqcap \forall \text{changeType}.\text{Create}$

$\text{ClassChange} \equiv \text{OntologyChange} \sqcap \forall \text{changeTarget}.\text{class}$

$\text{OntologyChange} \equiv \exists \text{changeTarget}.(\text{Class} \sqcup \text{Property} \sqcup \text{Individual} \sqcup \text{Ontology})$
 $\sqcup \exists \text{changeType}.(\text{Create} \sqcup \text{Update} \sqcup \text{Delete}) \sqcap = 1 \text{ changeAgent}$

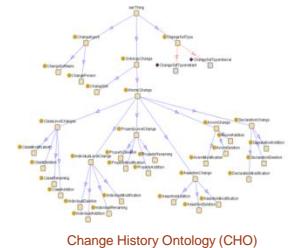
Logging



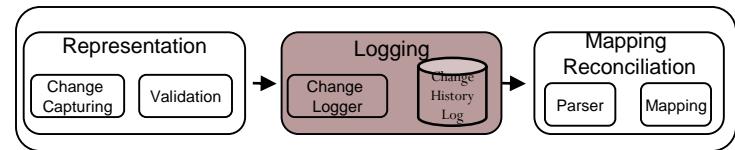
log:ChangeSet192

rdfs:type
 ch:hasChangeSetType
 ch:hasChangeAuthor
 ch:startTIme
 ch:endTime
 ch:hasChangeReason
 ch:targetOntology

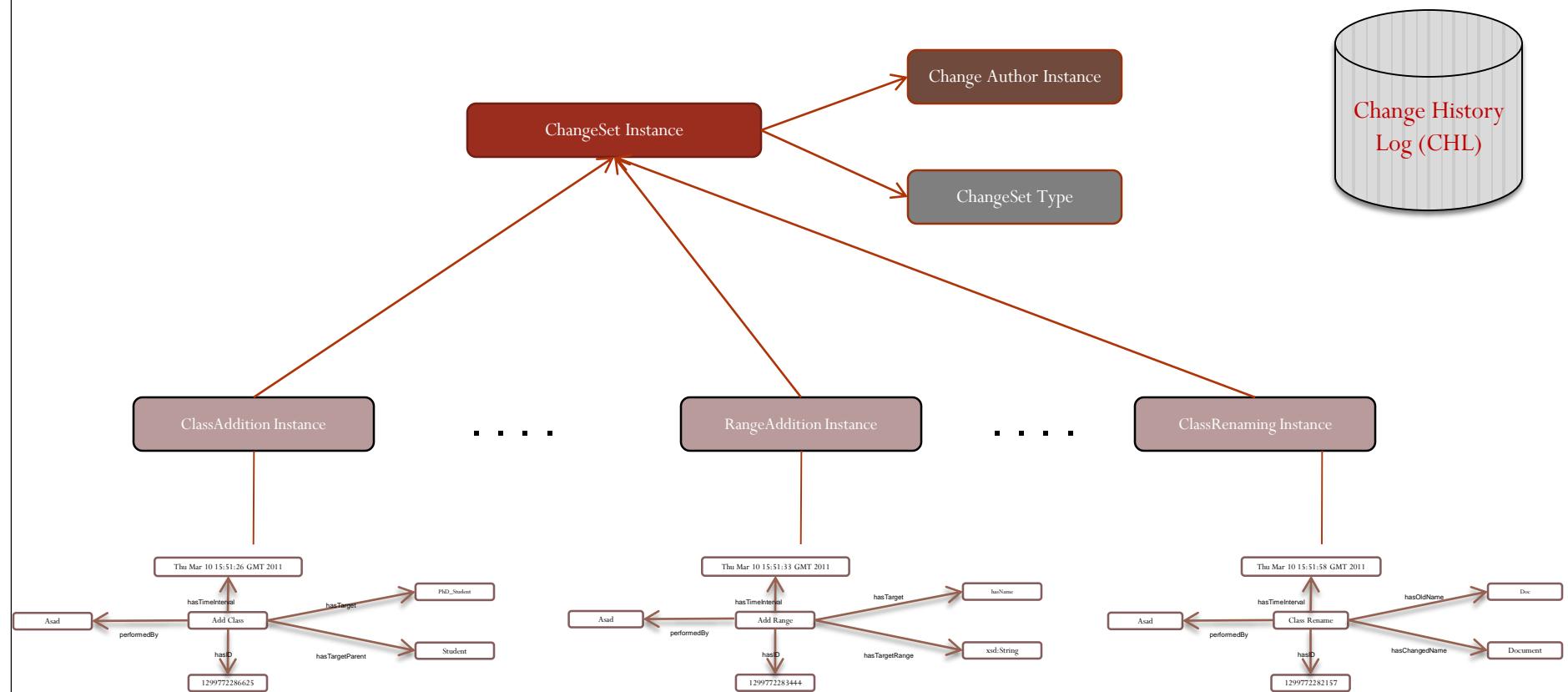
ch:ChangeSet ;
 log:Interval
 log:ChangeAgent2 ;
 "2010-01-02 16:32:58+1" ;
 "2010-01-02 16:53:11+1" ;
 "Changes after applying rigidity meta property.";
<http://seecs.nust.edu.pk/vocab/bib> .



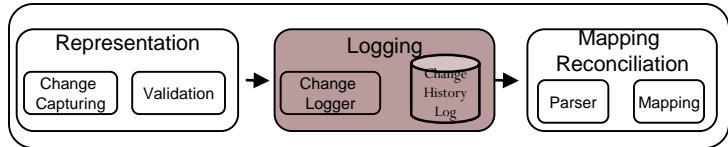
Logging



- Correspondence of a ChangeSet instance with the changes of particular change session



Logging



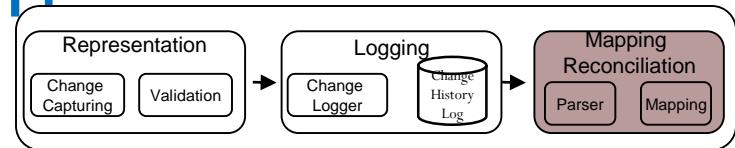
- Logged Changes
 - Validation and verification of the accurate changes is an essential and critical aspect for CHL.
- Change Capturing Validity
 1. Assuming two versions of an ontology: O_{V1} and O_{V2}
 2. And changes in both versions: C_Δ

Change Capturing Validity

$$O_{Vx} = O_{V2} - C_\Delta$$

$$\text{difference}(O_{V1}, O_{Vx}) = \emptyset$$

Mapping Reconciliation



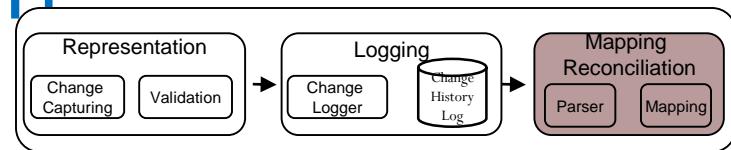
- **Mapping resolve** the terminological and conceptual incompatibilities.
 - For ontologies O_1 and O_2 , for each entity in O_1 , find a corresponding entity having same intended meaning, in O_2
 - $\text{map}(e_{1i}, e_{2j}) = \text{value}$
- **Mapping Reconciliation**
 - **Repairing and updating** the existing mappings due to changes in the participating ontologies.

- Asad Masood Khattak, Zeeshan Pervez, Khalid Latif, and Sungyoung Lee, "**Time Efficient Reconciliation of Mappings in Dynamic Web Ontologies**", Journal of Knowledge-based Systems, (IF:1.574), 2012.
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Mapping Reconciliation

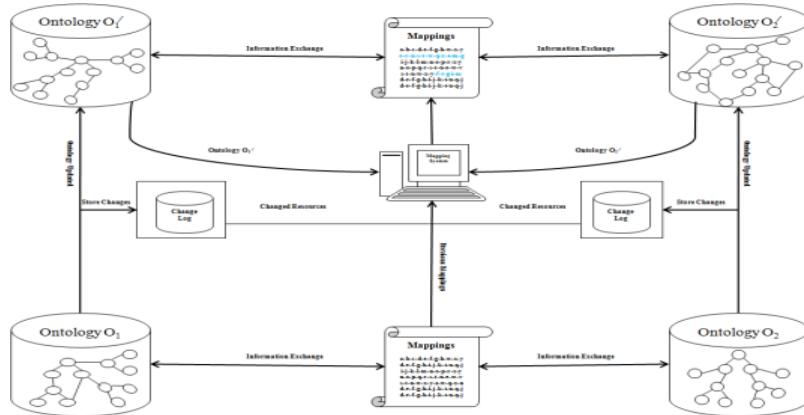
- Mapping Reconciliation Procedure

- Extract the ontology change information form CHL.



Resource: $\leftarrow \text{SELECT } ?\text{changes} \ ?\text{timeStamp} \text{ WHERE } \{?\text{changes} \ \text{docLog:isPartof} \ \text{changeSetInstance} . \ ?\text{changes} \ \text{docLog:hasTimeStamp} \ ?\text{timeStamp} \} \text{ ORDER BY DESC}(??\text{timeStamp})$

$\Delta_x: \leftarrow \text{SELECT } ?\text{changedTarget} \ ?\text{isSubClassof} \text{ WHERE } \{\text{Resource} \ \text{docLog:hasChangedTarget} \ ?\text{changedTarget} . \ \text{Resource} \ \text{docLog:isSubClassof} \ ?\text{isSubClassof}\}$

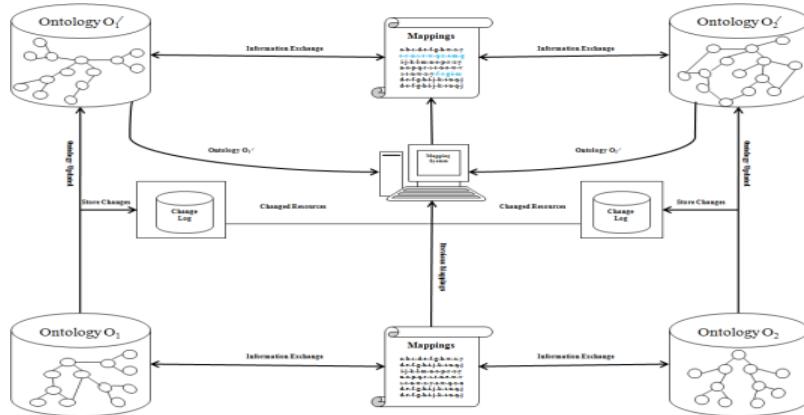
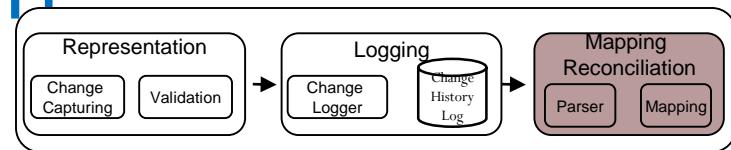


Mapping Reconciliation

- Mapping Reconciliation Procedure

- Read changed resources from CHL of both the mapped ontologies in Δ

```
If  $\exists \Delta \sqcap \Delta.O_1.CHL.NewChange$  then
    /* Read the changes in  $\Delta_1$  */
     $\Delta_1 \leftarrow \{x \mid x < CHL_{\Delta}, x > Change\}$ 
Endif
If  $\exists \Delta \sqcap \Delta.O_2.CHL.NewChange$  then
    /* Read the changes in  $\Delta_2$  */
     $\Delta_2 \leftarrow \{x \mid x < CHL_{\Delta}, x > Change\}$ 
Endif
```



Mapping Reconciliation

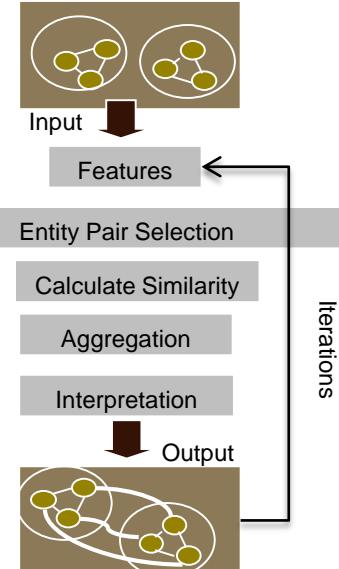
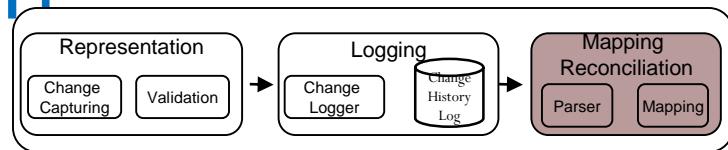
- Mapping Reconciliation Procedure

- Calculate Semantic Affinity to reconcile mappings

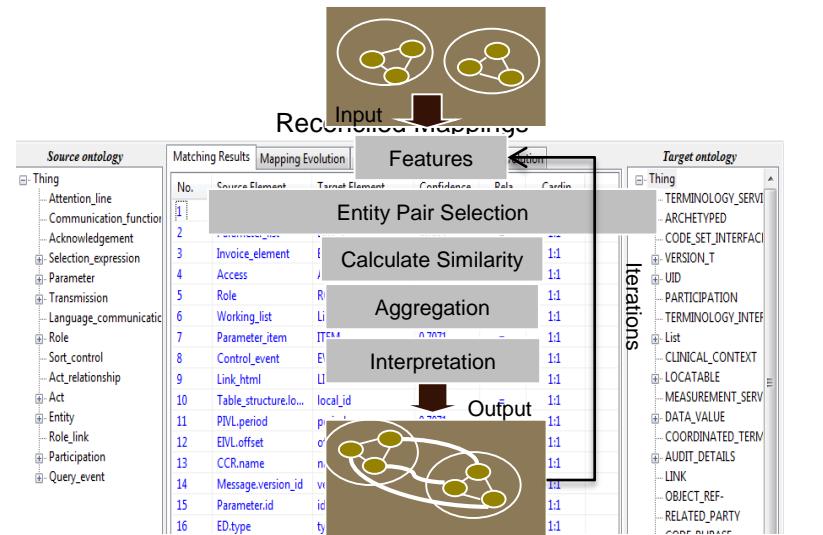
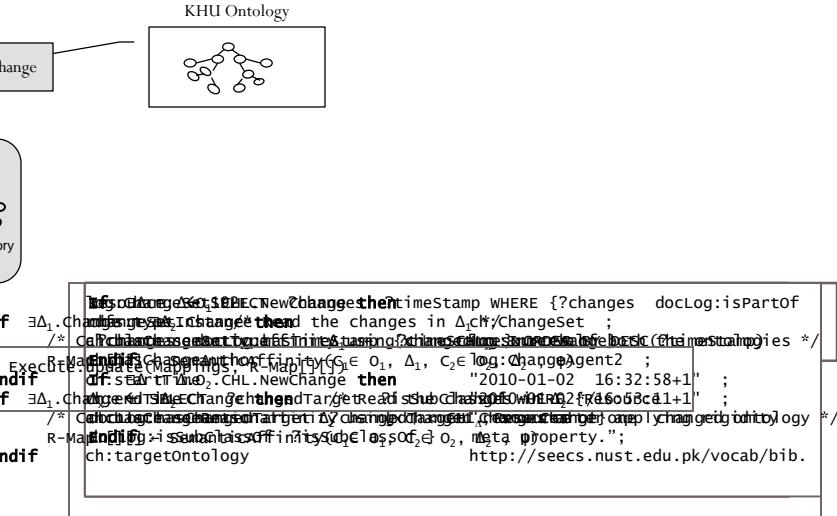
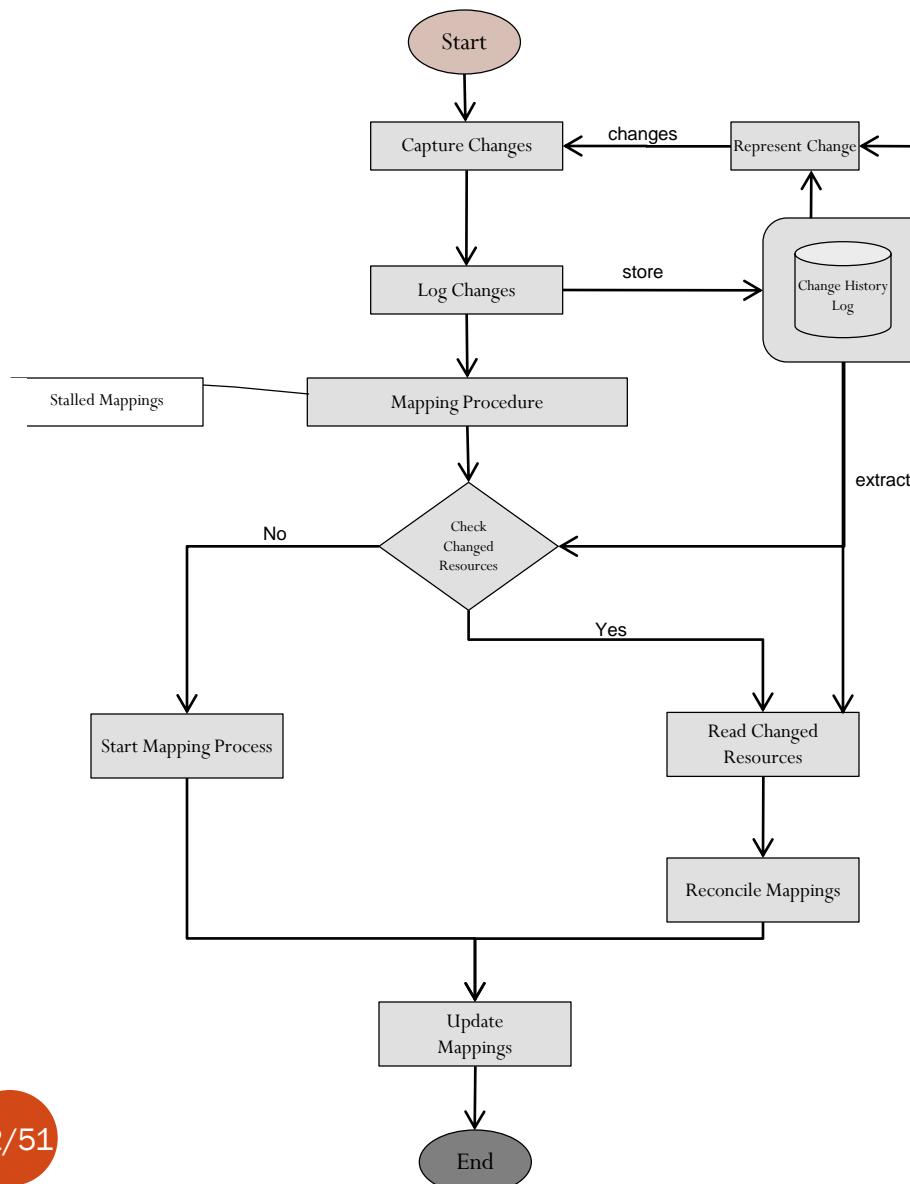
```
If  $\exists \Delta_1.\text{Change} \sqcap \exists \Delta_2.\text{Change}$  then
    /* calculate semantic affinity using changed resources of both the ontologies */
    R-Map [] []  $\leftarrow$  SemanticAffinity( $C_1 \in O_1, \Delta_1, C_2 \in O_2, \Delta_2, \psi$ )
Endif
If  $\exists \Delta_1.\text{Change} \sqcup \exists \Delta_2.\text{Change}$  then
    /* calculate semantic affinity using changed resources of one changed ontology */
    R-Map [] []  $\leftarrow$  SemanticAffinity( $C_1 \in O_1, C_2 \in O_2, \Delta_2, \psi$ )
Endif
```

- Update the original mapping file with the reconciled mappings

```
Execute.update(Mappings, R-Map[] [])
```



Overall Integrated Research Flow



Contributions

Contributions

- The significant contributions of this thesis are:
 - Change Representation and Logging
 - 94.71 % of Change Capturing Accuracy has been achieved
 - 100 % structural Change Logging accuracy has been achieved
 - Mapping Reconciliation
 - Time efficiency of 43 % to 85 % has been achieved
 - Proposed procedure consumes 41.11 % to 58.43 % Lesser Memory
 - Accuracy of 93.50 % to 100 % of existing mapping systems has been achieved

Experiments & Results

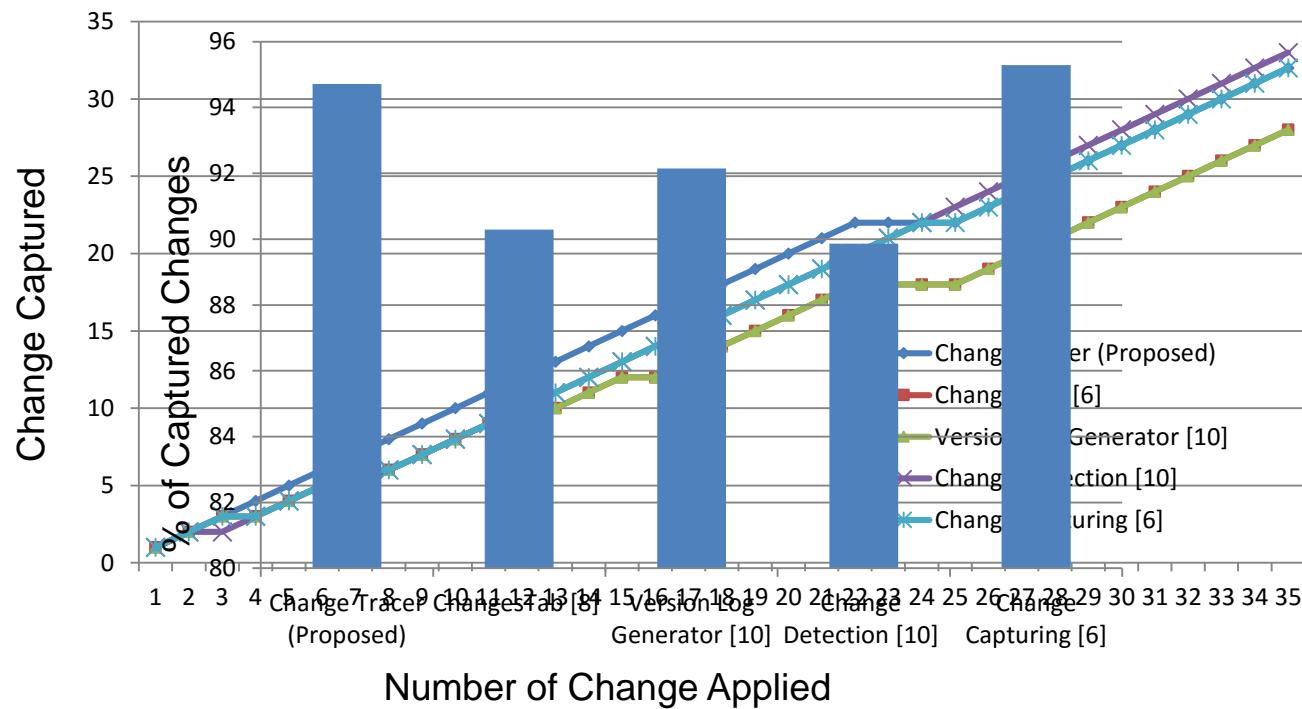
Experiments Environment

- Data Sets (16 Ontologies)
 - CRM [21], OMV [22], SWETO [23], SWRC [24], ACM and Springer [25], HL7 Classes [26], openEHR Classes [27]; GTT, GEMET, NALT, Human, Mouse, Food, and People+Pets [28]
- System Comparison (11 Systems)
 - Change Management
 - ChangesTab [8], Version Log Generator [10], Change Detection [10], and Change Capturing [6]
 - Mapping Reconciliation
 - FOAM [13], Falcon [14], H-Match [15], Prompt [16], Lily [17], AgreementMaker [18], and TaxoMap [19]

Experimental Results

- Change Capturing

Total Changes	Change Tracer	Changes Tab	Version Log Generator	Change Detection	Change Capturing
$700 = 35 * 20$	653	632	628	629	627
	94.71	90.28	92.14	89.86	95.28



Experimental Results

- Change Logging

Change Validation			
Tests	Correct Results	Problem	Accuracy
Initial Attempt: 12	5	Domain Addition DT Pr. Del. (Range)	41.47 %
1 st Revision: 12	7	Inverse Property	58.34 %
2 nd Revision: 12	12	Nil	100.00 %
Revised Validation			
Tests	Correct Results	Problem	Accuracy
36	36	Nil	100.00 %

Experimental Results

- Change Logging (Data sets)
 - SWETO `testbed_v1_2.owl`, `testbed_v1_3.owl`, and `testbed_v1_4.owl`
 - CRM ontology `cidoc-crm-3.2.owl` and `cidoc-crm-3.4.owl`

Ontology Versions	SWETO (V 1.2 & V 1.3)	SWETO (V 1.3 & V 1.4)	CRM (V 3.2 & V 3.4)
Total Changes	124	223	170
Change in Hierarchy	60	170	94
Change in Classes	107	193	54
Change in Properties	14	22	103

Experimental Results

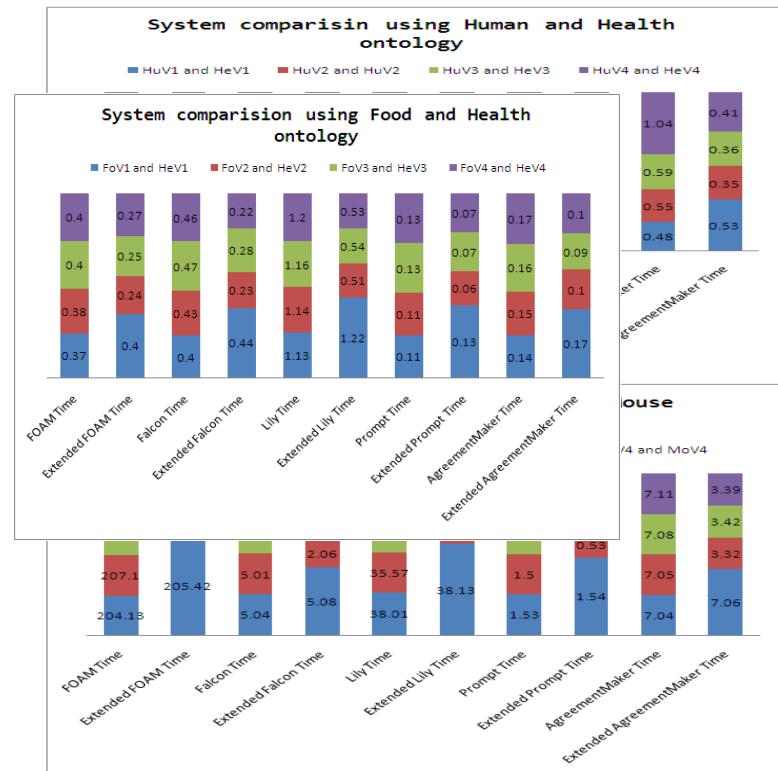
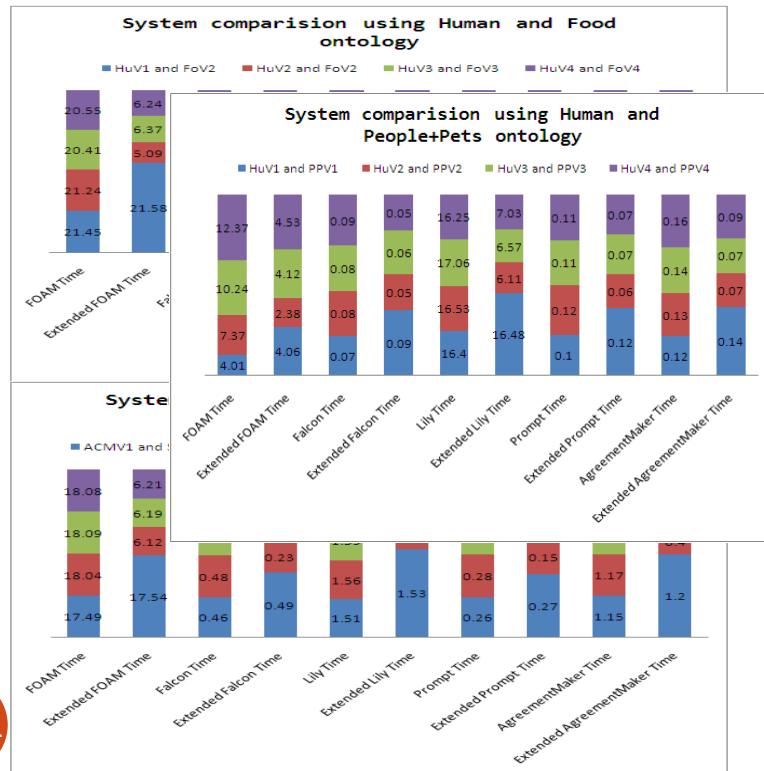
- Mapping Reconciliation (Complex Changes)
 - 25 set of changes

Mapping Systems	Mouse Onto vs. Human Onto	Brinkman Onto vs. GTT Onto	GEMET Onto vs. NALT Onto
Falcon Mapping Time	8.89 m	32.40 m	51.33 m
H-Match Mapping Time	10.76 m	39.13 m	1.12 h
Lily Mapping Time	13.22 m	34.03 m	52.65 m
TaxoMap Mapping Time	11.08 m	33.41 m	52.65 m
Falcon Re-Mapping Time	9.87 m	34.63 m	53.71 m
H-Match Re-Mapping Time	12.35 m	41.55 m	1.17 h
Lily Re-Mapping Time	15.43 m	37.20 m	54.97 m
TaxoMap Re-Mapping Time	13.21 m	35.93 m	55.36 m
Extended Falcon Re-Mapping Time	2.36 m	5.06 m	9.48 m
Extended H-Match Re-Mapping Time	2.96 m	4.88 m	12.39 m
Extended Lily Re-Mapping Time	3.45 m	6.75 m	10.37 m
Extended TaxoMap Re-Mapping Time	2.97 m	6.09 m	10.18 m

Experimental Results

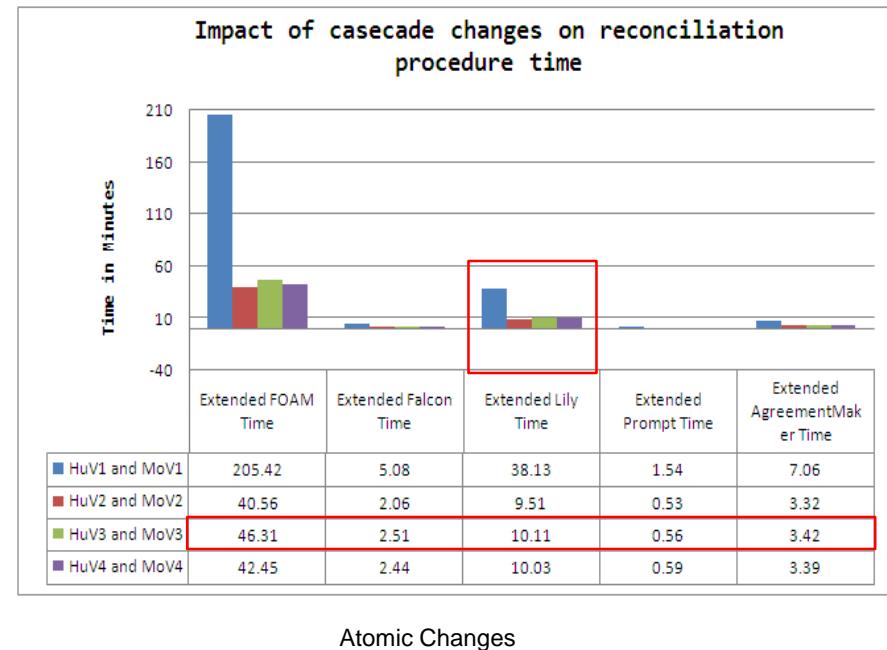
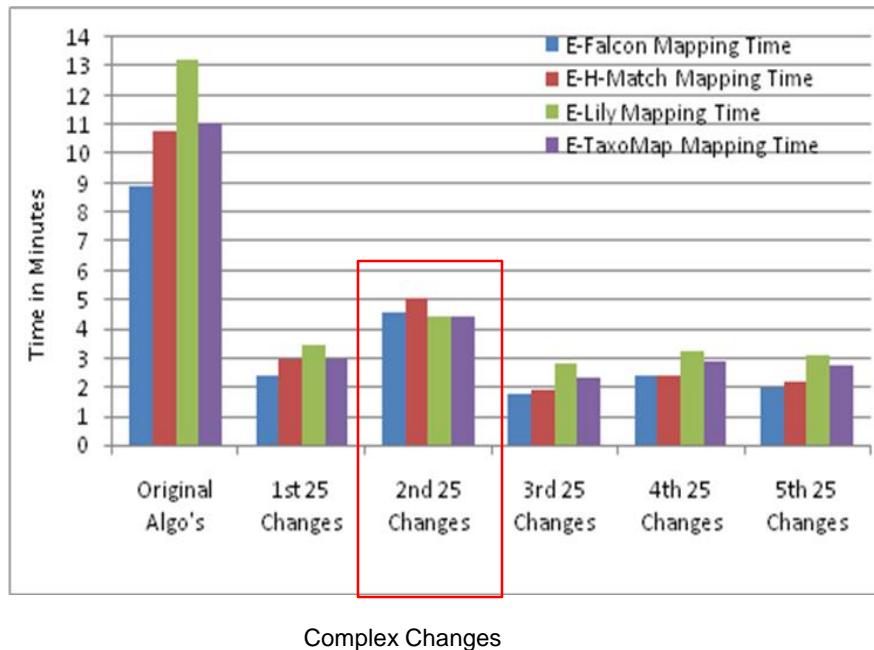
- Mapping Reconciliation (Atomic Changes)

Ontology Versions	Human	Mouse	Health	Food	People+Pet	ACM Ontology	Springer Ontology
Version1	Original	Original	Original	Original	Original	Original	Original
Version2 = Version1 + Changes	283	166	169	122	120	109	176
Version3 = Version2 + Changes	112	201	153	161	172	133	114
Version4 = Version3 + Changes	123	198	145	114	109	141	106



Experimental Results

- Cascading effects of ontology changes on dependent resources, still the proposed technique shows better performance. (Atomic and Complex Changes)
 - 5 set of experiments



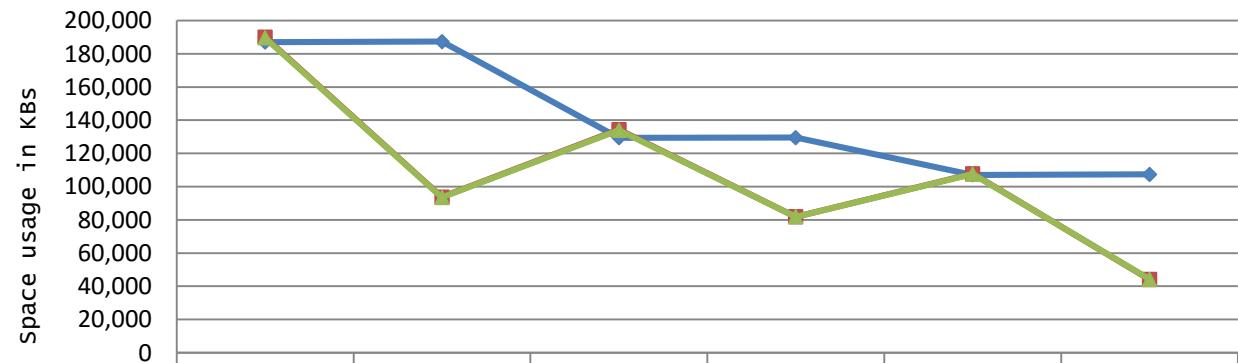
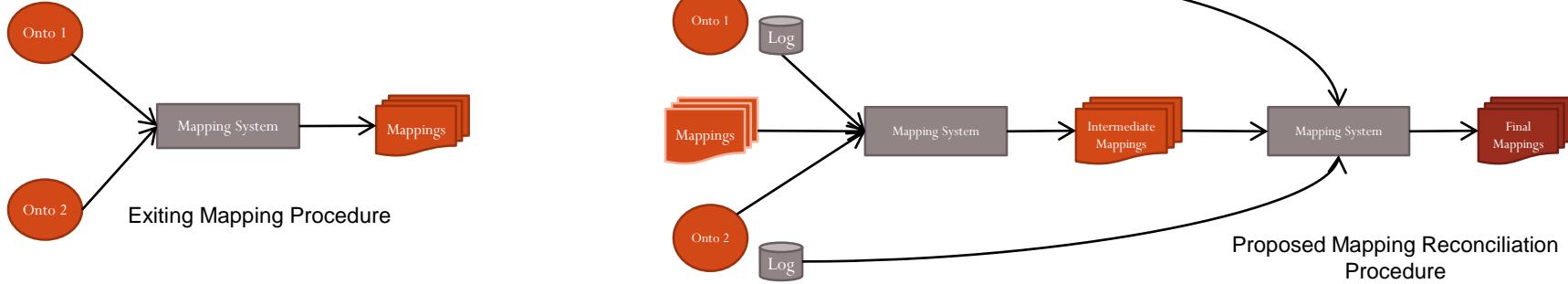
Experimental Results

- Reconciled Mapping Accuracy (Atomic Changes)

Ontology1	Ontology2	Changes	Ext-FOAM	Ext-Falcon	Ext-AgrMaker	Ext-Lily
HumanV1	MouseV1	Original	100%	100%	100%	100%
HumanV2	MouseV2	283 vs. 116	96.50%	96.50%	96.00%	96.00%
HumanV3	MouseV3	112 vs. 201	93.50%	95.00%	94.00%	95.00%
HumanV4	MouseV4	123 vs. 198	97.00%	97.00%	97.00%	97.00%
<hr/>						
HumanV1	HealthV1	Original	100%	100%	100%	100%
HumanV2	HealthV2	283 vs. 169	97.00%	98.50%	98.00%	99.00%
HumanV3	HealthV3	112 vs. 153	96.50%	96.00%	97.00%	97.00%
HumanV4	HealthV4	123 vs. 145	99.00%	100%	100%	100%
<hr/>						
HealthV1	FoodV1	Original	100%	100%	100%	100%
HealthV2	FoodV2	169 vs. 122	98.50%	100%	100%	100%
HealthV3	FoodV3	153 vs. 161	97.00%	98.50%	99.00%	99.00%
HealthV4	FoodV4	145 vs. 114	98.50%	99.50%	99.00%	100%
<hr/>						
ACMV1	SpringerV1	Original	100%	100%	100%	100%
ACMV2	SpringerV2	109 vs. 176	99.00%	100%	100%	100%
ACMV3	SpringerV3	133 vs. 114	98.50%	99.50%	99.00%	99.50%
ACMV4	SpringerV4	141 vs. 106	99.50%	100%	100%	100%

Experimental Results

- Memory usage during Reconciliation procedure (Complex Changes)



	Falcon Runtime Space Usage	Ext-Falcon Runtime Space Usage	Lily Runtime Space Usage	Ext-Lily Runtime Space Usage	TaxoMap Runtime Space Usage	Ext-TaxoMap Runtime Space Usage
Human vs. Mouse (Original)	187,003	187,320	129,393	129,544	107,061	107,392
HumanV1 vs. MouseV1	189,934	93,698	134,319	81,802	107,801	44,061
HumanV2 vs. MouseV2	189,544	93,491	134,002	81,854	107,566	44,132

Conclusions and Future Research

- This Thesis contribute to :
 - Designing and development of a **semantic structure** for ontology change history management.
 - **Capturing and logging** the changes in a coherent manner.
 - Reusing the logged changes for **mapping reconciliation**.
 - A high degree of **accuracy, performance, and resource utilization** against existing systems is achieved.
- Future Research
 - Structural and **Instance level** changes
 - **Variable accuracy:**
 - Mapping accuracy evaluation (missing mappings)
 - Reasons for missing mappings (Level of information, Conflicts at semantic level)

Future Applications

- CHL Repository
- Applications of CHL
 - Change Visualization
 - Ontology Recovery
 - Temporal Traceability
 - Query Reformulation
 - Collaborative Ontology Engineering
 - Adaptive Systems
 - Change Prediction



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Publications

Patents (2)

Two US Patents

One Korean Patent

SCI/E Journal Papers (7)

First Author

Co-author

Five Publications

Two Publications

Non-SCI/E Journal Papers (2)

First Author

Co-author

One Publication

One Publication

International Conference Papers (24)

First Author

Co-author

Fifteen Publications

Nine Publications

Total 33 Publications

Three Journal Papers are Under Review
(2 Major Revisions)

Asad Masood Khattak, Zeeshan Pervez, Chris Nugent, Sungyoung Lee, “**Adaptive System for Personalized Healthcare Services**”, IEEE Transactions on Biomedical Engineering, 2012. (In preparation)

Thank You

