NPS-CMIS-14-001

NAVAL
POSTGRADUATE
PSHOO

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704

THIS PAGE INTENTIONALLY LEFT BLANK

THIS PAGE INTENTIONALLY LEFT BLANK

HISHSN-1.15E1.15N-1.OTd   [.NA

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

A. PROBLEM STATEMENT

Traditional internet technologies, including the World Wide Web (WWW, W3), facilitate the access and presentation of networked data. These technologies have obvious applications in both classified and unclassified government systems, and make volumes of potentially useful information available to operational commanders and decisionconstructs provides for data

through existing Semantic Web technologies and includes a discussion of the use of metadata and ontologies, metadata frameworks and standards, ontology matching and

II. DESCRIPTION LOGICS AND KNOWLEDGE REPRESENTATION

A. DESCRIPTION LOGIC FUNDAMENTALS

DLs are a family of logic-based knowledge representation systems that fall

extensively by Semantic Web technologies. Specific $\mathcal{AL}$ extensions are

Role disjointedness (*disjoint*(r, s)) describes two roles as being mutually exclusive (i.e., if the first role holds for two individuals then the second role cannot hold for those same individuals).

A specific $\mathcal{AL}$-family DL is specified by the letter(s) associated with the extension(s) that it includes. For example, $\mathcal{AL}$

Based on this definition, an interpretation represents a full understanding of a domain of interest in t

3.

ABox if it satisfies all of the concepts and roles contained in the ABox. If the interpretation also satisfies the TBox then it amounts to a reasonable abstract view of the domain and is said to be a model for the ABox and TBox (Baader, et al., 07).

It is appropriate at this juncture to bring up two additional points. First, it is possible for the ABox and TBox to conflict. For instance, an ABox assertion “SurfaceUnit(Nimitz)” would conflict with the TBox definition of the “SurfaceUnit” interpretation. Finally, two concepts are disjoint i

This observation implies that if either satisfiability or subsumption is a decidable computational problem, then the entire set of TBox reasoning tasks are decidable. The ability to use satisfiability as the basis for reasoning about t

Given an individual, a, in

restriction: ɱ$(r_1$

3. Trigger Rules

A number of DL systems provide for the definition of inductive rules that can be used to extend KB. These rules are implemented as trigger rules expressed as FOL implications of the form

Submarine ṡ Military) although this might seem an intuitive implementation. From a

THIS PAGE INTENTIONALLY LEFT BLANK

III. SEMANTIC WEB IMPLEMENTATION

A.

Metadata is the fundamental underpinning of Semantic Web technologies—

intelligence assessments (i.e., inter-domain-specific metadata describing associations

can quickly become cumbersome in practice. Also, it is difficult or impossible to enforce relationships that might be obvious to humans. For instance, in the example “TU4” is a subordinate of “TU2”, so “TU4” should be assigned only to tasks that have been assigned to “TU2”. Unfortunately, there is no structural constraint that would prevent TU4’s assignment to a task associated with “TU1” or some other entity.

Figure 9.

uses a pattern matching paradigm that takes into account the relationships defined in the RDF document and governing RDF(S) schema (Kashyap, et al., 08). For example, the SPARQL query “SELECT $ordnance WHERE { $acft Type “F-16”, $acft AirOrdnance $ordnance }” will return all of the air ordnance carried by F-

Category	Operation	Examples

```
<owl:ObjectProperty rdf:ID="reportedBy">
  <rdfs:domain rdf:resource="#ContactReport"/>
```

Definition

Simple
Properties

Table 6

Conceptual scope

classes (Horrocks, et al., 08). Fortunately, authoring tools are available that make ontology development and maintenance tractable.

The following provides a short comparison of a number of commonly utilized tools for ontology development and maintenance. This summary focuses on tools that support OWL ontology development and maintenance. For a more complete comparison of the most ubiquitous tools, see (Kashyap, et al., 08), (Kapoor and Sharma, 10), and (Vidya and Punitha, 12).

(ita(BIR4(,310)):(t)-2nd Prtangence> reeeretare ontology development for database applications. IODE is a standalone system that represents knowledge using common logic (based on first-order logic)

between the two domains exploitable by applications as well. Similarly, formally defining the relationships between two disparate but related domains enables Semantic Web applications to exploit those relationships and use knowledge from both domains.

Figure 13. Independent ontologies applied to overlapping domains (potential overlaps indicated with dashed lines)

The problem of ontology matching can be formally defined as follows: given two ontologies O_1 and O_2, determine an alignment, A, defining correspondences between O_1 and O_2 where A is a set of correspondences defined as 5-tuples of the form $A_{id} = <$ id, e_1, e_2, n, r $>$ (Shvaiko and Euzenat, 08). The first tuple element, id, is a unique identifier for the specific correspondence. Elements e_1 and e_2 are entities (classes, relationships, individuals, data values, etc.) from O_1 and O_2, respectively, to which the correspondence is being asserted. The confidence in the alignment between entities $e_1$ng

Semantic matching utilizes model-

Figure 14. Ontology-based data integration techniques

With the single ontology

Country(a) Ẓ Unit(b) Ẓ Country(c) Ẓ

IV. DESCRIPTION LOGIC INFERENCING

Similar relationships are depicted in the ontology diagram depicted on the right. Specifically, “MilitaryAcft” and “CivilianAcft” are depicted as (disjoint) subclasses of “Aircraft”, practice, this reduction of standard reasoning tasks to subsumption and satisfiability also provides the basis for reasoning with ABox axioms.

Reasoning Task	

The worst-case scenario for reasoning about realization for an individual requires entailment testing of the individual for each concept in

the ABox while requirements for CQ and UCQ answering grows exponentially based on the number of named individuals in the ABox and the number of variables in the query (3-EXPTIME-Complete). Optimizations can eliminate large sections of the potential works by attempting to construct an interpretation that satisfies all of the ABox concepts and can be used to test the satisfiability of one or more concepts. The basic tableau algorithm for expressed in Negation Normal Form (NNF). NNF requires that all named concepts be atomic and that negations be applied only associated with a value

The third rule provides for qualified cardinality restrictions (the $\mathcal{ALCQ}$ DL) by adding “C(y)” to $\mathcal{A}_{Nj}$ and “¬C(y)” to $\mathcal{A}_{nj}$ for all y in the qualified role with x that are not already identified in $\mathcal{A}$ as either C or ¬C.

The fourth and fifth roles provide for role hierarchies (role/sub-role relationships) by modifying the existential quantification and value restriction rules of the original algorithm.

Finally, t

Automata-based algorithms have been utilized for many expressive DLs appro contains “s(x, z)” and the second contains “¬s(b, 5)”. The unification rule relies on a unification pairs of { b/x, z/5 } as to yield the following addition to the KB: “¬A even if they are not explicitly stated as ABox axioms. Reasoning

The second issue regards conflict resolution, which is of particular importance with forward chaining algorithms (but is relevant with backward chaining as well). If the KB is large, the conflict set is likelyl th0.004 Tw 0.26 0 Td   [(as)-5(w)-2 rules. In addition, RacerPro provides a number of interesting additions such as TBox and ABox retractions (i.e., non-monotonicity).

FaCT++ (Tsarkov and Horrocks, 06) is an open source reasoner providing full

C. NON-STANDARD DESCRIPTION LOGIC REASONING TASKS

With the exception of inductive rules, all of the reasoning tasks discussed thus far

LLY LEFT BLANK

ABox mining, this operation typically involves analyzing RDF statements to derive taxonomical classes and their relationships. Metadata extraction and ABox mining together can be used as sequential steps in the larger ontology extraction process.

Finally, the use of machine learning for application maintenance has been proposed as a means of improving Semantic Web services through analysis of user activity.

The general prem

background knowledge, B, a

satisfiability) but B does not full

It must be noted that inductive rules are not logically sound,

In addition to eliminating inconsistent hypotheses, the pruning function can be used to eliminate highly unlikely hypotheses. As discussed earlier, the application of learning algorithm population from a command and control system might contain tuples of the form “< contactID, contactType, contactSource >”. Individual members of the population set are called statistical units.

Features of interest for each for the population include both independent (or

a training process). If the comparison meets specified criteria, then the test individual is

Probabilistic Relational Models (PRM) are a form of RGM where nodes capture the probability distribution of object attributes and links represent relationships between objects. Early PRMs required that the relationships between objects be known, but extensions have made it possible to utilize PRMs to consider cases where relationships are unknown (Getoor, et al., 07).

VI. CONCLUSIONS AND RECOMMENDATIONS

A.

Ontology-

Highfleet Semantic Technologies, Integrated Ontology Development Environment online information, 2013. Available at http://www.highfleet.com/iode.html

Küsters, R and Molitor, R., "Structural Subsumption and Least Common Subsumers in a Description Logic with Existential and Number Restrictions", *Studia Logica: An International Journal for Symbolic Logic*, Vol. 81, No. 2, Nov., 2005.

Lin F. and Sandkuhl K., "A Survey of Exploiting WordNet in Ontology Matching" in IFIP International Federation for Information Processing, Vol. 276, Artificial Intelligence

Pease, A. (Ed.), IEEE Standard Upper Ontology Working Group online SUMO documentation, 2004. Available at http://suo.ieee.org/SUO/SUMO (accessed February 2013)

Sirin, E., Parsia, B., and Grau, B., Aditya Kalyanpur and Yarden Katz, "Pellet: A Practical OWL-DL Reasoner", *Journal of Web Semantics*, Vol. 5, Is. 2, June 2007.

Stanford University Center for Biomedical Informatics Research (CBIR), Protégé Online Documentation. Available at

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California

93Tj E