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Mandarax RDF / RDFS / OWL Extension

Agenda

- Mandarax RDF
- Mandarax OWL
- OWL2Prova / Hybrid Description Logic Programs
- Key Findings and Discussion

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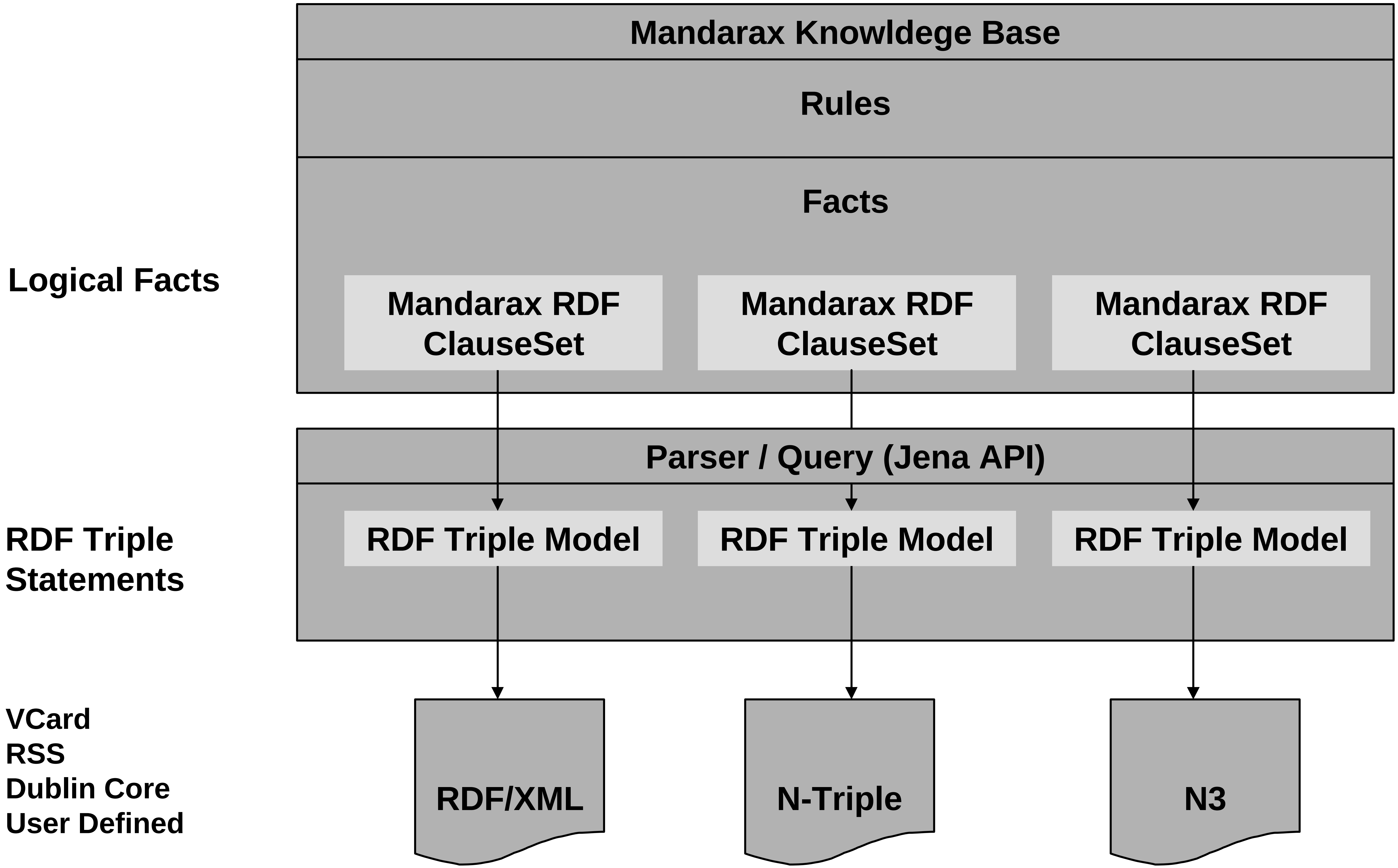
Mandarax RDF

Mandarax RDF Extension – Basic Concept



Mandarax RDF Integration

- RDF integration based on Mandarax Clause Sets: “RDFClauseSet”
- Iterator based: “RDFClauseIterator”
  - Wraps Jena RDF Interface
  - RDF model with Statements “S P O” is build at query-time via Jena
  - RDF model is queried via Jena “listStatement” to select predicates
  - Result “StmntIterator” is iterated
  - During iteration a Jena statement is mapped to a facts “p(S,O)”.
- Wrapper for Predicates: RDFPredicate
  - Structure {Object, Object}
  - Slots (Subject, Predicate)
  - Key: NS+local Name

RDFClauseSetIterator
RDFClauseIterator(URL, Pred)
+ hasMoreClauses(): boolean
+ nextClause(): Clause
+ close()

1. **Create model from URL**
2. **Select Statements → StmtIterator**
3. **Iterate StmtIterator**
   - has more statements
4. **Access next clause**
   - map statement to fact
5. **Release model**

RDF Mapping - Example

Rules / Queries

http://burningbird.net/postcon/elements/1.0/author (http://ibis.in.tum.de/staff/paschke/rbsla/index.htm, Author) ?

…

Mandarax Facts “Predicate(Subject,Object)

http://burningbird.net/postcon/elements/1.0/author (http://ibis.in.tum.de/staff/paschke/rbsla/index.htm, "Adrian Paschke“)
http://burningbird.net/postcon/elements/1.0/title (http://ibis.in.tum.de/staff/paschke/rbsla/index.htm, "Rule based Service Level Agreements“)

…

Tripel Statements “Subject Predicate Object”

[http://ibis.in.tum.de/staff/paschke/rbsla/index.htm, http://burningbird.net/postcon/elements/1.0/author, "Adrian Paschke"]
[http://ibis.in.tum.de/staff/paschke/rbsla/index.htm, http://burningbird.net/postcon/elements/1.0/title, "Rule based Service Level Agreements"]
[http://ibis.in.tum.de/staff/paschke/rbsla/index.htm, http://burningbird.net/postcon/elements/1.0/series, http://ibis.in.tum.de/staff/paschke/rbsla/index.htm]
[http://ibis.in.tum.de/staff/paschke/rbsla/index.htm, http://burningbird.net/postcon/elements/1.0/contains, "Information on the contract management project"]
[http://ibis.in.tum.de/staff/paschke/rbsla/index.htm, http://burningbird.net/postcon/elements/1.0/alsoContains, "Implementations"]

RDF / XML Data

```
<rdf:Description rdf:about="http://ibis.in.tum.de/staff/paschke/rbsla/index.htm">
   <pstcn:author>Adrian Paschke</pstcn:author>
   <pstcn:title>Rule based Service Level Agreements</pstcn:title>
   <pstcn:series rdf:resource="http://ibis.in.tum.de/staff/paschke/rbsla/index.htm" />
   <pstcn:contains>Information on the contract management project</pstcn:contains>
   <pstcn:alsoContains>Implementations</pstcn:alsoContains>
</rdf:Description>
```

Usage Example

```
// Set Up KB and add RDF ClauseSet

KnowledgeBase kb = new AdvancedKnowledgeBase();
URL url = this.getClass().getResource("articles.rdf");
RDFClauseSet clauseSet = new RDFClauseSet(url);
kb.add(clauseSet);


// Query KB with RDF data


Query query1 = lfs.query(
        lfs.fact(RDFLib.pred(RDFLib.NS("pstcn"),"author"),
        lfs.variable("Article", Object.class),
        lfs.variable("Name", Object.class)),"query");
ResultSet rs = ie.query(query1,kb,InferenceEngine.ALL,InferenceEngine.BUBBLE_EXCEPTIONS);


// Print Result Set


while (rs.next()) System.out.println(
        "Author of "+rs.getResult(Object.class,"Article")+" is "+ rs.getResult(Object.class,"Name"));
```

Properties of the Mandarax RDF API (1)

- Pre-fetching of predicate keys
  - Needed for indexing of clause sets
  - Done at construction time of Clause Set
  - Problem: large RDF models

- Containers (SEQ,ALT,BAG) and Collections (Linked Lists)
  - Several contents
  - Triple representation with bNodes

```
<rdf:Description rdf:about="http://burningbird.net/earthstars/contest.htm">
 <pstcn:photos>
  <rdf:Bag>
   <rdf:li rdf:resource="http://burningbird.net/earthstars/capo.jpg" />
   <rdf:li rdf:resource="http://burningbird.net/earthstars/baritea.jpg" />
   <rdf:li rdf:resource="http://burningbird.net/earthstars/cfluorite.jpg" />
   <rdf:li rdf:resource="http://burningbird.net/earthstars/ccinnibar.jpg" />
   <rdf:li rdf:resource="http://burningbird.net/earthstars/baryto.jpg" />
   <rdf:li rdf:resource="http://burningbird.net/earthstars/cbarite2a.jpg" />
  </rdf:Bag>
 </pstcn:photos>
</rdf:Description>
```

Containers / Collections (2)

[**9f7e9a5:1098836ea34:-8000**, http://www.w3.org/1999/02/22-rdf-syntax-ns#_2, http://burningbird.net/earthstars/baritea.jpg]

[**9f7e9a5:1098836ea34:-8000**, http://www.w3.org/1999/02/22-rdf-syntax-ns#type, http://www.w3.org/1999/02/22-rdf-syntax-ns#Bag]

[http://burningbird.net/earthstars/contest.htm, http://burningbird.net/postcon/elements/1.0/photos, **9f7e9a5:1098836ea34:-8000**]

[**9f7e9a5:1098836ea34:-8000**, http://www.w3.org/1999/02/22-rdf-syntax-ns#_1, http://burningbird.net/earthstars/capo.jpg]

- Problem querying Containers/Collections
  - bNode IDs change
  - <u>unordered</u> triples

- Solution:
  - Wrapper for Collections and Containers: RDFContainers, RDFCollections
  - Lazy initialization during RDF2Fact mapping
  - Overwrite “equals” method to compare contents at query-time

Properties of the Mandarax RDF API (2)

- Reification
  - Reified statement: “(Subject Property Object) Property2 Object2”
  - Translation into 5 facts

    type(StmtID, Statement)
    subject(StmtID,Subject)
    object(StmtID,Object)
    property(StmtID,Property)
    property2(StmtID,Object2)

- Namespaces
  - Fully supported
  - Predefined namespaces in RDFConstants (RDF, XMLS, DC, VCARD, RMS …)
  - Namespace Map + mapping method: RDFLib.NS(prefix) returns namespace

    RDFLib.NS(“rdf”)+”type” expands to “http://www.w3.org/1999/02/22-rdf-syntax-ns#type”

- RDFLib (under rdf.lib)
  - Factory methods for creating RDF content: subj(URI),obj(URI),pred(URI),lit(value)

- Caching of Facts <u>and</u> Models (cache timeout can be set)

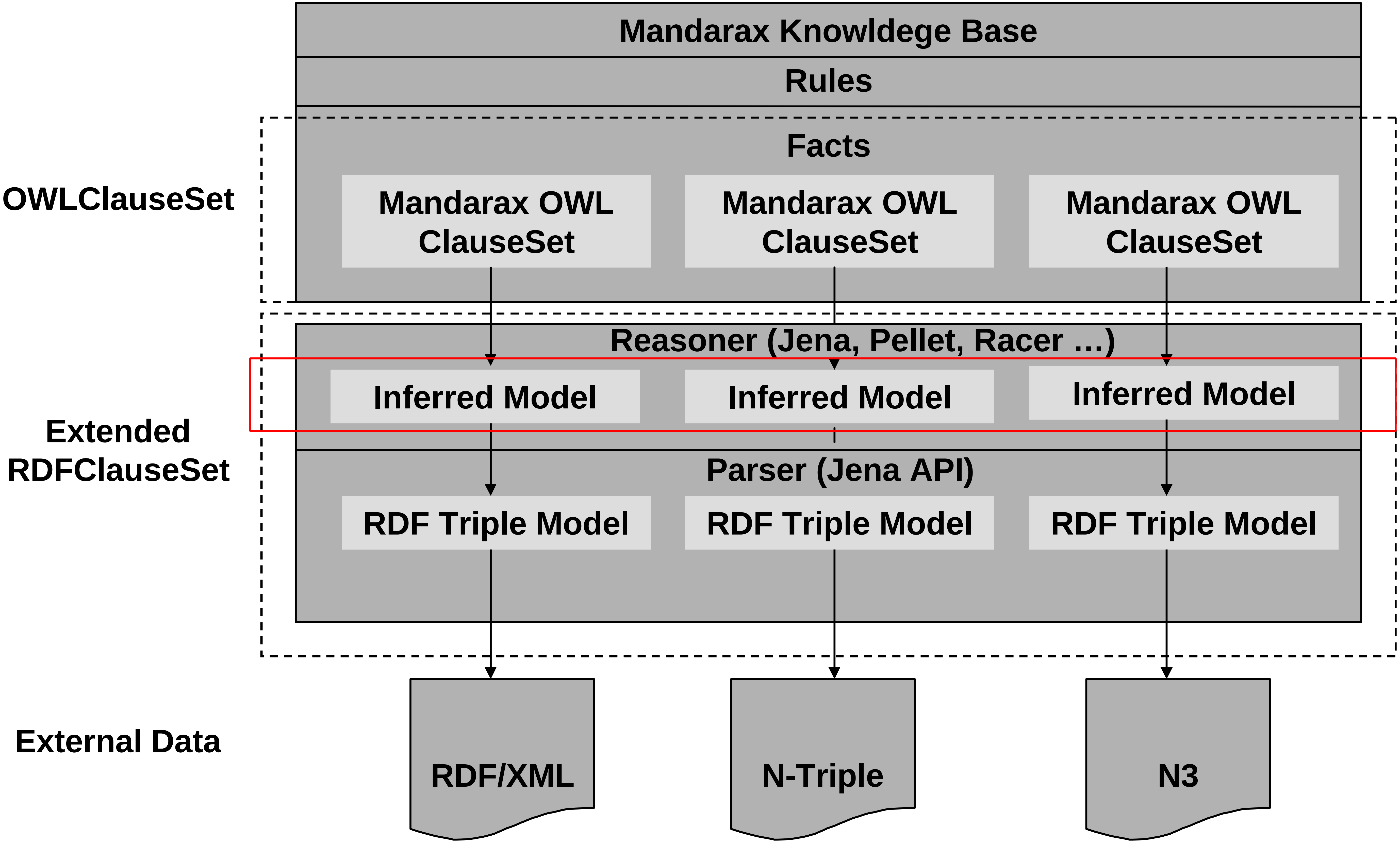
- TestCases + Examples (test.org.mandarax.rdf / org.mandarax.rdf.examples)

Mandarax OWL

Mandarax OWL

- Provides inference support for RDFS, OWL (Lite, DL), DAML, SWRL??
- Build on top of Mandarax RDF
- Two basic approaches:
  1. External reasoner (Jena) to infer model and answer queries
  2. Built-In inference rules on top of Mandarax RDF facts
- OWLClauseSet and OWLClauseIterator wrap RDFClauseSet and RDFClauseIterator

Approach 1: External Reasoner



Mandarax OWL with External Reasoner

- Mandarax OWL support:
  - Transitive reasoner: traversing class and property lattices
  - RDFS reasoner: RDFS entailments
  - OWL reasoners: OWL Lite entailments
  - OWL DL (via Pellet)
  - SWRL (planned within Pellet)

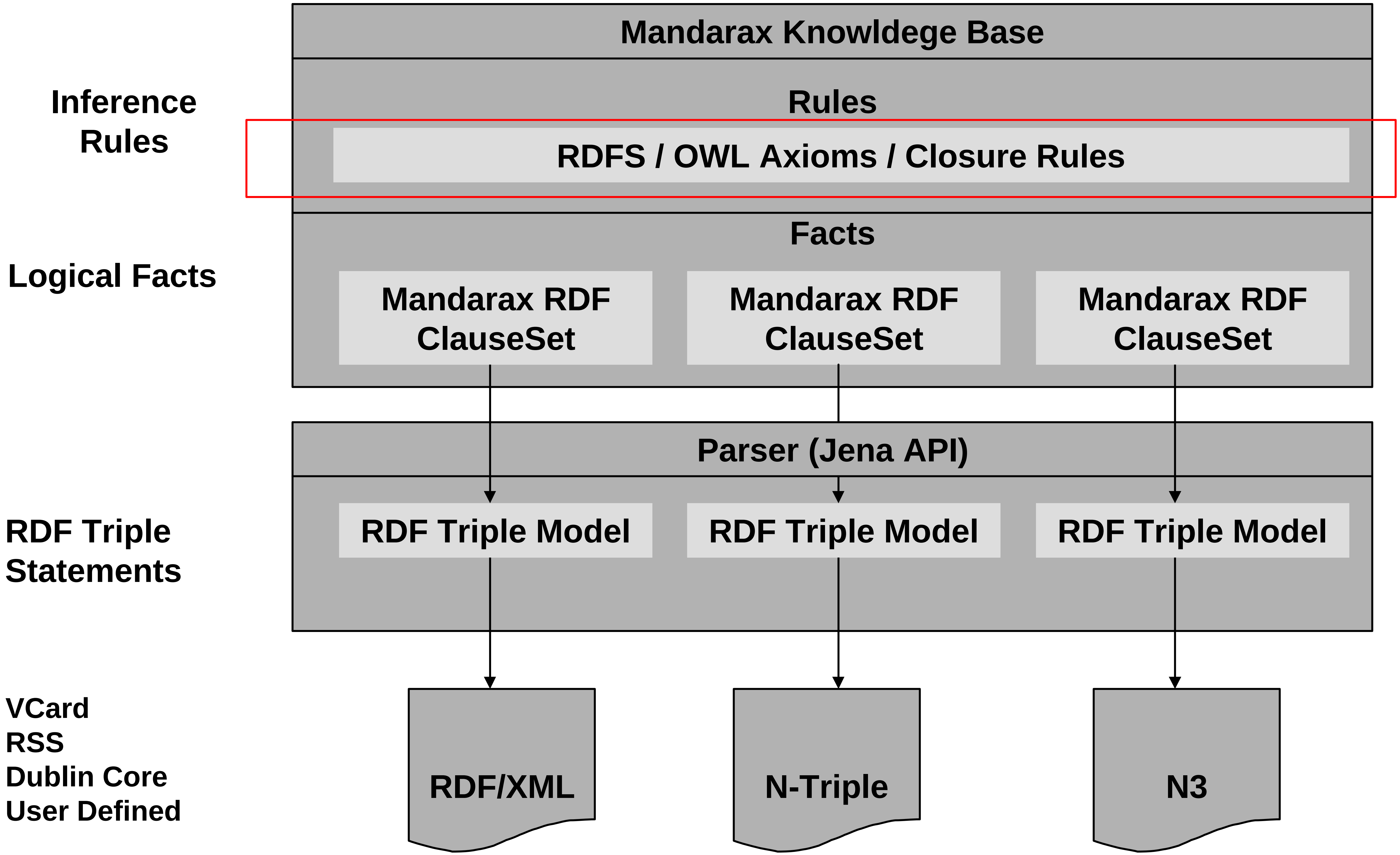
- Inferred model is build on top of default RDF model at query time

- Caching of inferred models supported and useful !!!!
  - Each subgoal derivation creates new Iterator with new inferred model
  - Needs efficient garbage collector in resolution implementation
  - Close() releases resources

- Special treatment of properties needed for reasoning over user-defined properties
  - Mandarax RDF transformation "Class1 Property Class1" => property(Class, Class) excludes free property queries: "c1 Property? C2"
  - Solution: Additional mapping in OWLClauseterator to "property(P, C1, C2)"
  - Note:
    - property(p,C1,C2)? queries are internally transferred to normal queries p(C1,C2)?, .i.e. restricted search space
    - property(P,C1,C2)? queries with free property variable are applied on the complete model, i.e. more expensive

- Problem: RDFPredicates in rule heads not entailed in original model

Approach 2: Built-In Inference Rules



Approach 2: Built-In Inference Rules

- Based on a plug-in module concept
  - A set of inference rules is defined as a module which can be plugged-in the KB
  - Helps to control the level of inference
- Implemented in OWLLib (owl.lib)
  - Defines reusable RDF/RDFS/OWL predicates: TYPE, SUBCLASSOF, DOMAIN etc.
  - Factory methods for creating RDF/RDFS/OWL content
    - instance() create instances / individual
    - property() create properties
    - clazz() create classes
- Currently 5 plug-ins:
  - Transitive Inference Rules (subclassOf, subPropertyOf)
  - RDFS Axioms
  - RDFS Inference Rules
  - OWL Axioms
  - OWL Inference Rules

Inference Rules - Examples

- Inference Rules
  - RDFS Inference

rdfs:domain(P , C), property(P ,X ,Y) -> rdf:type(X , C)
rdfs:range(P , C), property(P ,X ,Y) -> rdf:type(Y , C)
rdfs:subPropertyOf(A , B), rdfs:subPropertyOf(B , C) -> rdfs:subPropertyOf(A , C)
rdfs:subClassOf(A , B), rdfs:subClassOf(B , C) -> rdfs:subClassOf(A , C)
rdfs:subPropertyOf(P , Q), property(P, A, B) -> property(Q, A , B)

  - OWL Inference

owl:equivalentClass(P,Q) -> rdfs:subClassOf(P, Q)
owl:equivalentClass(P, Q) -> rdfs:subClassOf(Q, P)
rdfs:subClassOf(P, Q), rdfs:subClassOf(Q, P) → owl:equivalentClass(P,Q)

owl:disjointWith(C, D), rdf:type(X, C), rdf:type(Y,D) -> owl:differentFrom(X, Y)

rdf:type(P, owl:SymmetricProperty), property(P, X, Y) -> property(P, Y X)

owl:equivalentProperty(P, Q) -> rdfs:subPropertyOf (P, Q)
owl:equivalentProperty(P, Q) -> rdfs:subPropertyOf(Q, P)
rdfs:subPropertyOf(P, Q), rdfs:subPropertyOf(Q, P) -> owl:equivalentProperty(P, Q)

…

Axioms - Examples

- RDFS Axioms

  -> (rdf:type rdfs:range rdfs:Class).
  -> (rdfs:subPropertyOf rdfs:domain rdf:Property).
  -> (rdfs:Resource rdf:type rdfs:Class).
  -> (rdfs:Literal rdf:type rdfs:Class).

  …

- OWL Axioms

  -> (owl:equivalentProperty rdf:type owl:SymmetricProperty).
  -> (owl:equivalentProperty rdf:type owl:TransitiveProperty).
  -> (owl:equivalentClass rdf:type owl:SymmetricProperty).
  -> (owl:equivalentClass rdf:type owl:TransitiveProperty).
  -> (owl:sameIndividualAs rdf:type owl:SymmetricProperty).
  -> (owl:sameIndividualAs rdf:type owl:TransitiveProperty).

…

Key findings: Built-in inference rules

- Loop Checking needed
  - SLD (with negation as finite failure): subclassOf(A,B), subclassOf(B,C) → subclassOf(A,C)
  - Manadarax LoopChecker does not work ??
  - Simple loop checker implemented in OWLLib
  - Better solution: extend resolution, other semantics, e.g. well-founded
- Performance most of the time slower than with external reasoner
  - Mandarax resolution needs to be improved
- Currently: Incomplete implementation in particular for OWL
  - First test with some inference rules;
- Useful for transitive reasoning: transitive plug-in
  - e.g. typed logic, i.e. using RDFS taxonomies as type system
- Useful for reasoning of **derived** RDF predicates and updates
  - e.g. subclassOf(A,B) :- body.
- Useful for combination with other logics, e.g. defeasible priority reasoning in case of ontology conflicts.
- Better control of inference layer
- Further optimization can be applied, e.g.
  - Bound testing and rule variants
    - bound(C) rdfs:domain(P, C), property(P, X, Y) -> rdf:type(X, C)
    - free(C) property(P, X, Y), rdfs:domain(P, C) -> rdf:type(X, C)
  - Description logic programs (DLP)
    - subclassOf(C,D) maps to C(x) -> D(x) => reduces search space
  - ….
- Problems: functional properties, existential restrictions, cardinality restrictions
  - Needs rules with equality in the rule heads and existential restrictions and counters of variable bindings

OWL2Prova

OWL2Prova

- Flexible framework to reason over RDFS / OWL data
- Precompilation
  - Converters are used to translate RDF statements into arbitrary output facts
  - SimpleConverter translates to arbitrary outputs according to user-defined patterns, e.g:
    - ["predicate","subject","object"] => predicate(subject,object)
    - [“rdf", "subject","object"] => rdf(subject,object)
    - [“rdfTriple","subject","predicate","object"] => rdfTriple(subject,predicate,object)
  - DLPConverter translates to description logic programs:
    - C(X) → D(x) class C is subclassOf class D
    - P(x,y) → Q(x,y) property P is a subproperty of property Q
    - P(x,y) → C(y) range of property P is class C
    - C(X)→D(X)
    - D(X)→C(X) Class C and Class D are equivalent
    - etc.

    - **Needs loop checker** – OWL2Prova adds a kind of memoization of critical subgoals in order to prevent loops
  - Further user-defined converters can be easily added, extending the Converter interface
- Supports different reasoners such as Transitive, RDFS, OWL, OWL Mini etc. to infer a model (precompile) and translate it
- The precompiled and translated models can be consulted into an existing KB

OWL2Prova (2)

- Special dynamic query predicate
  “*rdf(file, reasoner, subject, predicate, object)*”
  “*rdf(url, subject, predicate, object)*”
- Wraps external reasoner (Jena / Pellet) which is used for query-answering
- Result list with variable bindings can be iterated and used in the further resolution process
- Advantages
  - Variables over predicates / properties possible ➔ enables reasoning
  - No need to pre-fetch predicate names for indexing
  - Only one RDF predicate must be indexed – no need for indexing (prefetching) predicate keys
  - Note: Search space will be constrained by subject, predicate, object

Might be useful for Mandarax RDF / OWL ????

Typed Hybrid Description Logic Programs

- Build on OWL2Prova Integration of Jena API and Pellet Reasoner
- Hybrid Description Logic Programs
  - LP reasoner for hybrid DL-typed rules
  - External reasoner (DL reasoner Pellet)
- Types Systems: Order Sorted OWL / RDFS Type Systems (Ontologies)
- Polymorphic Order-Sorted Unification Algorithm in ContractLog KR
- Terms are typed with type from Semantic Web ontology
- Subsumption reasoning for type checking
- Instance reasoning for Individual → Class / Type reasoning
- Decidable with Datalog restriction
- Exptime (OWL-Lite) resp. NEXPTIME (OWL-DL)
- More Information:
  - Paschke, A.: Typed Hybrid Description Logic Programs with Order-Sorted Semantic Web Type Systems based on OWL and RDFS, Internet Based Information Systems, Technical University Munich, Technical Report 12/05, 2005.

Summary

- Mandarax RDF / OWL enables rules on top of Semantic Web Data
  - Combine rules and description logics
    - Negation
    - Semantic Web taxonomies for term typing in rules
    - Use logical concepts to handle conflicts and incomplete knowledge, e.g. defeasible logic
    - Etc.

- Mandarax RDF
  - Provides basic RDF integration
  - Optimizations possible

- Mandarax OWL
  - Provides built-in inference rules and external reasoner
  - Various optimization can be applied
  - Test cases are needed (e.g. W3C tests)
  - External “reasoner approach” more efficient

Thank you for attention !!!!

Discussion