Abstract:

As far as I know, RDF / RDF(S) or OWL are not currently widely adopted in the enterprise, in favor of more traditional methods of information storage and retrieval such as RDBMSs and, also, NoSQL datastores. This seems like the benefits of 'semantic' datastores are only visible to a selected group of 'gurus' and that no mortal will be able, or even need, to take advantage of SW.

There must be a better way than an 'all or nothing' approach where one paradigm takes over another. Simple CRUD/ERP, BI and even Enterprise Application Integration (ESB) problems currently lack of 'ontologies' in favor of 'schemas' or interfaces when the former could be of great help when managed from the governance perspective of an organization.

Having a 'kind' of semantic repository, which is aware of all 'triples' the integrated systems 'produce' (Adapters), has previous knowledge of the 'world' (augmented/loaded with domain ontologies), performs type inference and ontology merge and alignment, resolves inferred links from new knowledge and aggregates this knowledge into layers: from raw data to symbolic statements to (inferred) behavior statements may be the foundation (via a functional API) of a Master Data Management (MDM) like 'semantic' component. Component have Adapter(s): kind of 'driver' for each datasource/format, that feeds triples from the sources to the component keeping them in sync.

Proposed implementation details of the component discussed below involve many low level concepts which are specific to this attempt of data integration and are not necessary 'orthodox' SW practices. In the end, the component offers a set of ports/endpoints for different protocols/services with similar semantics so it can be used by many clients as possible as a 'MDM Hub'.

Alignment to an ‘upper’ ontology which could map our knowledge with well known vocabularies is a possibility by the means of a ‘OWL Runtime’ and a little bit of extra API to make it available to semantic tools. One of the features introduced in this implementation is the notion of a resource having many types as it occur in different places so this runtime shall allow for a ‘standard’ view of the knowledge stored.

Scope

Build an elemental repository component of semantically augmented data, information and knowledge for business applications data backend. Includes temporal analysis features for BI like applications.

RDF Backed: multiple data sources/formats translated to Triples by Adapters (Drivers for RDF import/sync). Knowledge database features.

Distributed 'peers' support for instances sharing of knowledge. Data coming from different sources in the form of raw triples without a schema will be classified, linked and merged (if they refer to the same subjects).

Type inference. Alignment & merge of different (imported) ontologies. Relationships & link discovery (reasoning). Augmentation of source knowledge.

Raw categorized data to be aggregated into facts, information (semiotically) and knowledge (behavior) metamodel levels. Rules (productions), Events and Flows (state) inference for declarative building of application logic at behavior level.

Set oriented metamodel layers abstraction for resource aggregation. Temporal contexts for statements. Eventual & logical order. Functional programming interface for models. 'Ports' for interfacing via known protocols with the knowledge base.

BI and Linked Data enabled platform at semantic knowledge backend level: The above mentioned features could make the concepts of the framework a solid backend for this kind of applications, suitable for flexible, platform independent, middle and presentation tiers implementations. This solution and the ability to merge diverse datasources/formats and to provide uniform interfaces are advantageous at the time to decide for a specific backend or narrow to a RDF only solution.

Introduction

The framework proposed here is not a ‘pure’ semantic web application framework in its strict sense but is more a workaround for implementing a functional programming / protocol frontend backed with set theory reasoning for type inference and ontology alignment and merge of diverse knowledge bases. It also attempts to provide a unified interface for data (facts), information (signs) and knowledge (behavior) SPO metamodels for load, query and manipulation of those entities in a functional and declarative fashion.

This is to be accomplished with the development of a component, named ‘MDM Hub’ with features akin to a relational database ones, in the sense that it is a ‘low level’ storage component but with the semantics and reasoning perspective of the Semantic Web (and its corresponding interfaces).

Resources, Sets

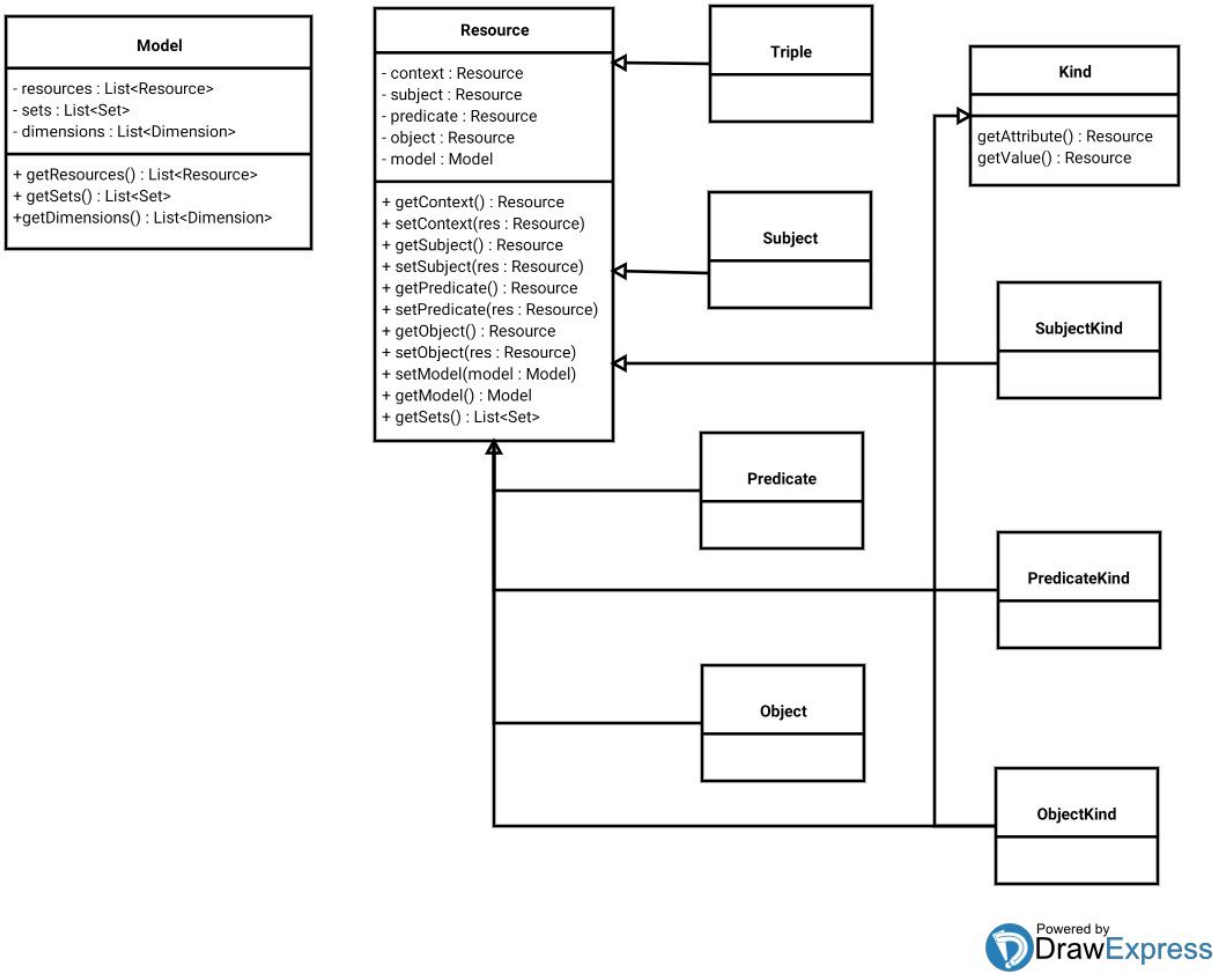
For the sake of our attempt in modelling semantic/semiotic structures (semantics are a branch of semiotics that deals with signs and the objects they refer), all three layers of (meta)models which deal with triples are represented with instances of Resource(s) which are arranged in a pseudo (multi)set structure.

The first level: data (facts) deals with ‘pure’ source RDF CSPO statements. It corresponds with the management of ‘signs’ (SPOs URIs) and the semiotics branch of ‘syntax’ (the study of signs and their relationships).

The second level: information (objects, signs and concepts) adds a ‘meaning’ layer to previous pure signs, treating them all (SPOs of the previous level) as a single statement triple (here named Topic) part, its Object. It also treats previous level Triples and Kinds as its Subject and Predicate, respectively, in its Topic triples (more on Kinds and how to use them below). This resembles more accurately what ‘semantic’ means in a semiotic context.

The third level: knowledge (behavior) aggregates the previous level in the same manner than information level did with data level. Roughly this level will correspond with semiotics branch ‘pragmatics’. The intention here is to infer as much as possible ‘state’ knowledge regarding the occurrence of events, the application of some rule or the conditions of some workflow.

The Sets section depicts graphically in pseudo multiset diagram what has been told here. The following diagram shows the Resource hierachy in pseudo UML for graphical purposes.



A Resource has an URI and this URI may play multiple occurrences in multiple Resource(s). A Resource may play many roles. It reifies another Resource(s) as its own CSPOs (it's a quad). The roles a Resource may play are: Triple, Subject, Predicate, Object and their corresponding Kind(s).

Kind(s) are the 'type information' collected from the triples an SPO occurs in. A Kind have 'attribute' and 'value' fields corresponding to which part of a statement they classify. For example, a SubjectKind aggregates Predicate attributes and then their Object values to group the Kind instance into a 'class' (same Predicates) and a 'metaclass' (same class, same Object(s)). The same is for Predicate and Object Kind(s), changing their corresponding attributes and values from the statements they occur.

Classes and metaclasses, Kinds, are (reified) Resources (Set predicates: TBD) and have their own URIs (hierarchical: set/superset attrs/vals). For example, the SubjectKind for employees have a Subject reifying itself (and all the Employee set).

Encode Kind metadata in SPOs. TBD.

In sets sense, a SubjectKind can be considered as being in the intersection of the Predicate and Object sets because it has the corresponding attribute and value fields populated. TBD.

Kind's Resource encoding allows to reify all its metadata, attributes and values using the context for the metaclass URI (more on contexts and triples: TBD) and the SPO part that would be, ie.: S for a SubjectKind, for the class URI. For being able to look for Kind information: retrieve attributes and values from triples with Resource occurring and then look up for corresponding matching Kind(s).

Resource instantiation:
When a (meta)model layer receives a set of triples it instantiates the corresponding triple Resource(s), it then de-aggregates the corresponding Kind(s) attribute/value instantiating Resource(s): PO Resources for SubjectKind, SO Resources for PredicateKind, SP Resources for ObjectKind. So, Kind(s) may be seen as the 'intersection' of the two complementary sets of a given one. Then it instantiates Resources for; Subject, Predicate and Object sets.

Evaluation of the Resources by the Sets API determines which Set each belongs to. In any level of the three models layers the behavior is the same. Sets in each level are given a different name to differentiate its purpose, meaning or usage. Another level(s) of model(s) could be added below or on top the ones here and those names will be 'relative' (SPO, OCS, TSP).

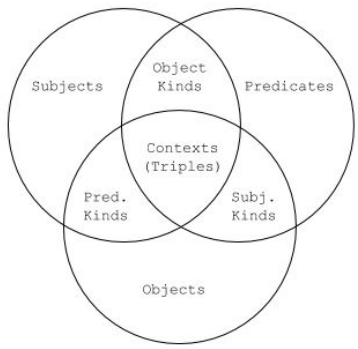
Name resolution API: An API should be provided that resolves entity names (identifiers) in namespaces or contexts maybe resolving such name as a property or relative to another entity. Infer Kind names (Employee). Align and merge (if two names resolve to the same, recursively?) TBD.

ResourceIDs (introduced later) are a mean of constructing 'semantically rich' hash codes, basically for lookup optimization in the Services API mappings and grammars and Sets. They should allow to build (LISP like) expressions which addresses in simple or complex forms a Resource or set of Resources.

ResourceIDs will be the 'selector' syntax for functional operations discussed below. The Services mappings and grammars will be the (persistence-able) model and represents the same Resource data as the Set model.

Sets

SPO Model (Facts)



Occurrence	Attribute	Value
Subject	Predicate	Object
Predicate	Subject	Object
Object	Predicate	Subject

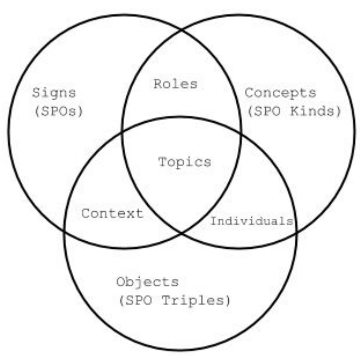
Triples:

```
Occurrences (Subject ex.):
[context / time] [SubjectURI] [classID] [metaClassID]

Kinds:
[metaClassID] [classID] [attribute] [value]

Contexts:
[context / time] [Subject] [Predicate] [Object]
```

As discussed above, here is the data layer metamodel, with just sign triples (CSPO URIs). A sample statement could be:

(someNewsArticle, subject, climateChange)

Semiotic Model (SCO, Contexts)



Occurrence	Attribute	Value
Sign	Concept	Object
Concept	Object	Sign
Object	Concept	Sign

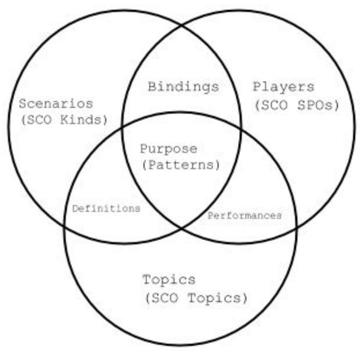
Triples:

```
Occurrences (Object ex.):
[context / Topic] [ObjectURI] [classID] [metaClassID]

Kinds:
[metaClassID] [classID] [attribute] [value]

Contexts:
[Topic] [Object] [Concept] [Sign]
```

Here is the information layer metamodel. It adds a semantic (semiotic) refinement to previous triples. Aggregating data we could infer this information (Topic triple):

(someMedia, names, ecology)

Behavior Model (TSP)



Occurrence	Attribute	Value
Scenario	Topic	Player
Player	Scenario	Topic
Topic	Scenario	Player

Triples:

```
Occurrences (Topic ex.)
[context / Purpose] [TopicURI] [classID] [metaClassID]

Kinds:
[metaClassID] [classID] [attribute] [value]

Contexts:
[Purpose] [Topic] [Scenario] [Player]
```

And the knowledge (behavior/pragmatics) model should show which state changes (or interactions) are taking place in our dataset. A sample triple (Purpose) would be:

(mention, mentions, mentionable)

Events, Flows and Rules:
According the type of predicate (Scenario) of a triple at this knowledge level there are three kind of possible Bindings:

For a SCO Role: Event Binding.
For a SCO Context: Rule Binding.
For a SCO Individual: Flow Binding.

Definition holds for possible Bindings state transition kinds. Performance holds for instances of given state transition executions.

Rule: A & B : C. C & D : cause(D, C).
(Fever & Cold : Flu. Flu & lowTemperature : cause(lowTemperature, aFlu).

Flow: A : B, C... according condition.
Given some Kind possible next Kinds.

Event: Employee : Promotion (good emp.). Identify / reify event and kind of event.

TSP Purpose statement contexts aggregates / sorts Rule's, Event's and Flow's instance triples temporally / logically.

Ordering of triples and events:
In most example statements (quads) contexts are omitted. Quad contexts encode metaclass metadata for Kinds / SPOs and temporal metadata for Triples. The metaclass of a given resource occurs at a given point in time. Time metadata should be encoded such as comparisons may shield an octal value as a result. Regarding an octal digit it can be represented by 3 binary digits, each one representing the comparison result for past, present, future and overlapping values of one statement respect to another.

Sets API

An uniform API should exist enabling sets definitions, population and manipulation for all three metamodel layer levels. Each set will be defined by a Predicate which determines if a Resource belongs or not to him. Previously, all types of Resource(s) must be de-aggregated from the level input triples.

Level(s) input triples shall be meaningfully aggregated/created from previous level entities. Operations over (inter) level sets will be those of traditional set operations, plus operations enabling to ‘join’ or navigate related set elements (Subject - Triples - SubjectKinds).

Services / OWL Runtime

Services API is the core component for model persistence and provides mappings and grammars for ease of Functional API implementation, along with Sets API and ResourceIDs.

The mappings provided are: Index, Naming and Registry. They resemble functions (maps) which returns an entity given two other entities of the other types. The types mapped are: URIs, Kind(s) and Triples. There is how the functions look like:

Index(URI, Triple) : Kind
Naming(Triple, Kind) : URI
Registry(Kind, URI) : Triple(s).

A grammar is a description of a (set of) Resource(s). It will be implemented with ResourceIDs ‘selectors’ and will be populated with ‘automata’ like inferencing.

Equivalent grammars should represent equivalent resources so they should be merged if name resolution (discussed above) yields equivalent names for equivalent relationships.

Peers Hubs may perform distributed resolution and merge. Selectors (ResourceIDs) may have a textual syntax and a forms-like serialization. The can be used as (dynamic) dataflow placeholders (Protocol dialog) if implemented as Resources.

An OWL upper ontology will be developed for alignment with existing/new vocabularies and ontologies (for example ISO15926). An endpoint (Port) shall be provided for interaction with this view of the store.

Functional API

Listeners for behavior (Events, Rules, Flows). TBD.

Selectors: Map, iterate, aggregate, query, traversal. TBD.

Bound functions. Monads. CoSQL. TBD.

ResourceIDs (TBD)

A ResourceID is a 'semantically rich' hash code. It serves as a 'selector' for Resources and have a LISP like form of declaration.

ResourceID form: TBD
ResourceID : ([TripleID, ResourceID pattern | TripleID mask])*;

The right part of the expression is a (variable) input and the TripleID is the context in which to evaluate the output of the expression. Forms can be complex with sub forms at the tail of the expression.

The intention is to use the statements component identifiers (CSPO, in binary form) to create a binary mask that will hold true for the desired output applying it as a filter for model resources.

ResourceID expressions
A resource can match to one or more resource expressions concatenated in the form:

(ResultAggregate, SourceAggregate) (LHSJoinMask, RHSJoinMask) (Mask, InputMask)

where each of the expression parts are ResourceIDs having their input on its right and their outputs on their left sides. The intention here is to define an aggregation task only by using selectors. TBD.

Grammars, of Services component, are implemented through ResourceIDs. The IDs are inferred from existing resources and similar resources will hold for selection of this given grammar.

TripleIDs and patterns/mask are composed together using the binary OR of its parts and the resulting mask applied to an (ordered) set of IDs resulting in the selection of matching instances.

Align and merge / Inference

Relationship (links) inference example: X coworker Y (same employer). Develop discover algorithms. Infer link types (grammars). Use Kinds, classes, metaclasses (Kinds) relations. TBD.

Infer attributes / rels from class (emp, sal, dept, manager) from links. Mgr. is emp's dept. leader. TBD.

Infer type by contents: Occurrence having other Kinds in other contexts. Grammar (abstract) occurrences of subject, context merge. Sort Kinds: Grammar hiers (parent). Adult - CanDrive. Employee must be Person & Student. ResourceIDs. Phone number has area code. Infer keys. TBD.

Search

The component basic job is to reply a request with content in the response relevant to the request contents by exact match or by similarity. It persists all queries as such and the client is allowed to repost a refined request based on the initial/sucesive responses.

Temporal relationships. Construct expression (diagnose, cause). Example. TBD.

Protocol

Based on search. Submission of triples returns relevant triples (reified Kinds). The main purpose of this framework is to provide a low level lightweight knowledge database component. If submitted triples implies a state change or behavior corresponding data triples for such update are sent in the response and the client customizes this update ‘template’ and submits the update information.

Protocol modes:
Submission of

(foreignProducts, increaseTax, 5%)

triple as request input produces and returns the TSP generated triples (‘fires’ rules, events, flows) as the response for the next request that, when submitted, materializes / updates definitions and triples into sets and services models. Also a ‘priceIncrease’ event may be fired if two correlated (by purpose context) occurs and there exist a performance and roles kinds for the scenario and player parts of the TSP triple.

Definitions: Materialize SCO, TSP .(Reified Kinds) into SPO. Query for ‘priceIncrease’ events, rules and flows matching given criteria. TBD.

Deployment (TBD)

Datasources. Adapters. Peers. MDM Hub. Load / Align. Deploy. Stacks. Internal architecture. Jena. DOM. Listeners (Behavior). Activation.

Ports:
REST / HATEOAS
RDF(S) / OWL
SPARQL
OData
SOAP
Solid

Application

Dashboard. TBD.

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