Semanta: An Ontology Driven Semantic Link Analysis Framework

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Outline

- Motivation
- Problem Statement
- Semantic Links & Queries
- Semantic Network
- System Architecture
- Traversing the Semantic Links
- Conclusions and Future Work

Motivation

- Information overload
  - Many users are increasingly overwhelmed by the amount of information available
  - Examples:
    - Biomedical research, investigative or watchdog journalism
- Knowledge Starvation
  - Inability to make informed decisions backed by facts not easily discernible
- Semantic Web
  - Advances have made it possible to effectively capture the knowledge of a domain through various markup languages
- Tools aiding information analysis are needed in handling knowledge starvation

Problem Statement

- A framework for finding semantic links among entities is needed for effective decision-making
  - Links are previously unknown or hidden within knowledge-bases and/or information resources
  - Finding them might be a very cumbersome task for users

Semantic Links

- A transitive link between any two entities/classes

  E.g. Finding possible relationships between the Energy sector and the Republican Party of United States

- User may have preferences over links to be found (i.e., entities linked by a specific relation)

  E.g. Finding entities that are related to Saddam Hussein through the positive-associate relationship.

Challenges

- A relatively new scientific problem
- No existing mechanisms for querying semantic links
- Need for an orchestrated query mechanism for both knowledge-bases and information resources
- Finding useful links and presenting the results

Semantic Network

Semantic Network

- Objective
  - To effectively capture data in various domains
- Layers of knowledge and information
  - Ontology Layers
    - Class Base Layer
    - Object Base Layer

    Fairly static
  - Information Source Layer

    Dynamic
- Advantages:
  - The idea of “an ontology-driven search” for semantic links
  - Reduce cost

Class Base Layer

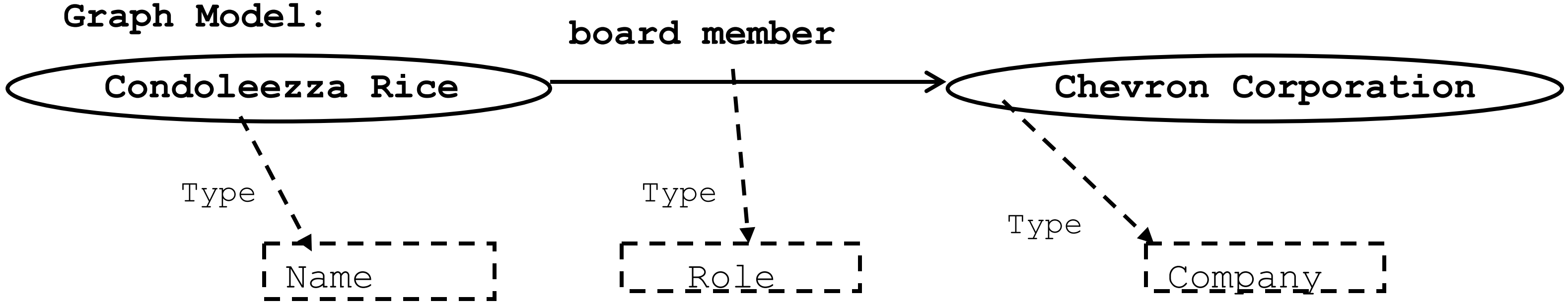
- Concepts
  - Name
- Relationships
  - Parent-child
  - Container relationship
  - User-defined – e.g. works-for, mother-of
- Resource Description Framework Schema (RDFS)
- Schema files capture the concepts of a specific domain
- Uniform vocabulary across schema files

Object Base Layer

- Instances of concepts
- RDF files

Statement: Condoleezza Rice is a board member of Chevron Corporation

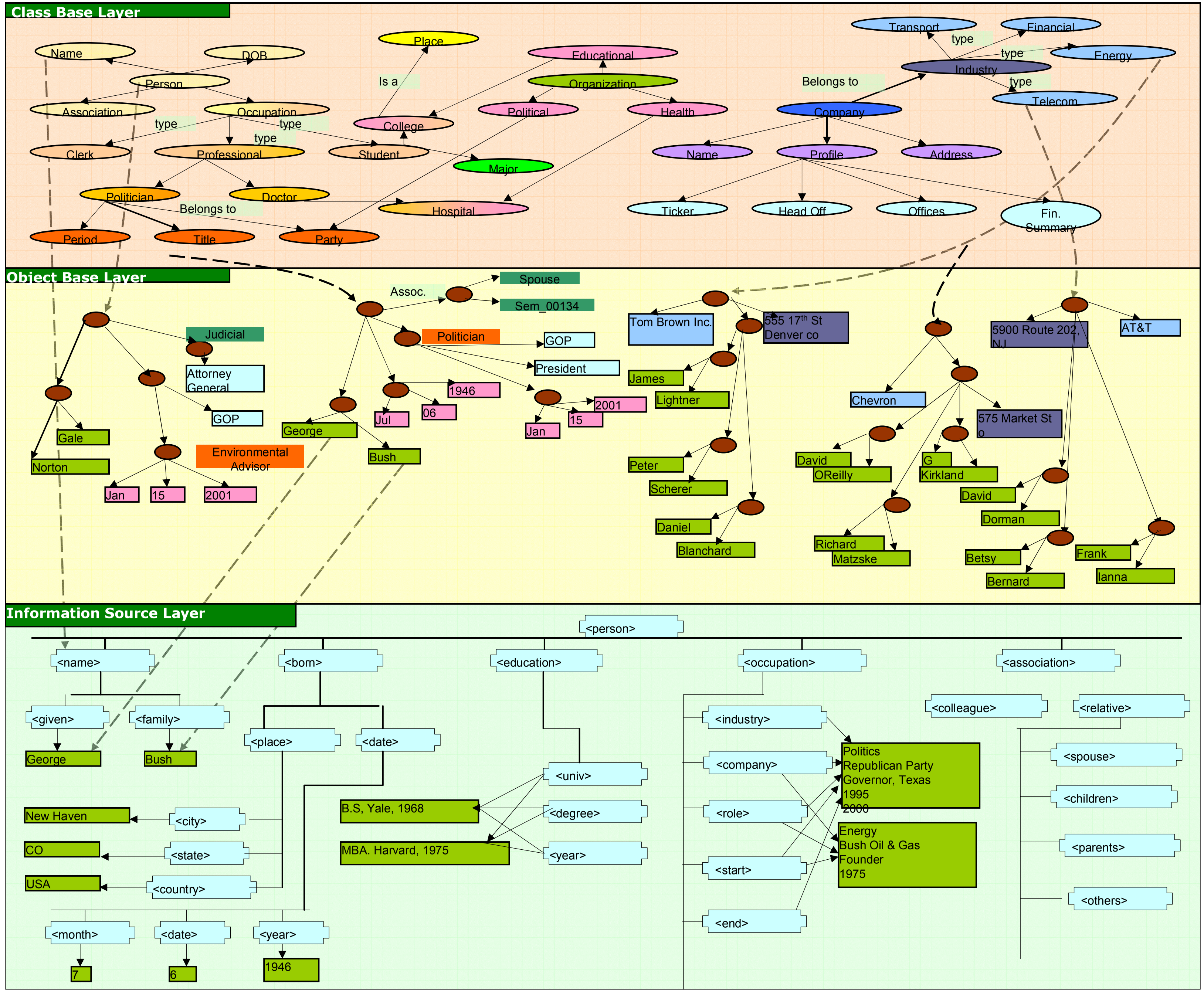
Graph Model:



Triplet: <Condoleezza Rice> <board member> <Chevron Corporation>

Information Source Layer

- Source for richer and fresh information
- Complements domain knowledge in the Ontology layers
- Defined using multiple XML documents
- Shares the same vocabulary with other layers



Class Base Layer
Name
DOB
Person
Association
Occupation
Clerk
Professional
Student
Politician
Doctor
Period
Title
Party
Place
Is a
College
Major
Educational
Organization
Political
Health
Hospital
Belongs to
type
Transport
Financial
Energy
Industry
Telecom
Company
Name
Profile
Address
Ticker
Head Off
Offices
Fin. Summary
Object Base Layer
Assoc.
Spouse
Sem_00134
Judicial
Attorney General
GOP
Gale
Norton
Environmental Advisor
Jan
15
2001
Politician
President
George
Bush
Jul
06
1946
Tom Brown Inc.
555 17th St Denver co
James
Lightner
Peter
Scherer
Daniel
Blanchard
Chevron
575 Market St o
David
OReilly
G
Kirkland
Richard
Matzske
5900 Route 202, NJ
AT&T
Dorman
Betsy
Bernard
Frank
Ianna
Information Source Layer
<person>
<name>
<born>
<education>
<occupation>
<association>
<given>
<family>
<place>
<date>
<univ>
<degree>
<year>
<city>
<state>
<country>
New Haven
CO
USA
B.S, Yale, 1968
MBA. Harvard, 1975
<month>
7
6
1946
<industry>
<company>
<role>
<start>
<end>
Politics
Republican Party
Governor, Texas
1995
2000
Energy
Bush Oil & Gas
Founder
1975
<colleague>
<relative>
<spouse>
<children>
<parents>
<others>

Semantic Link Queries

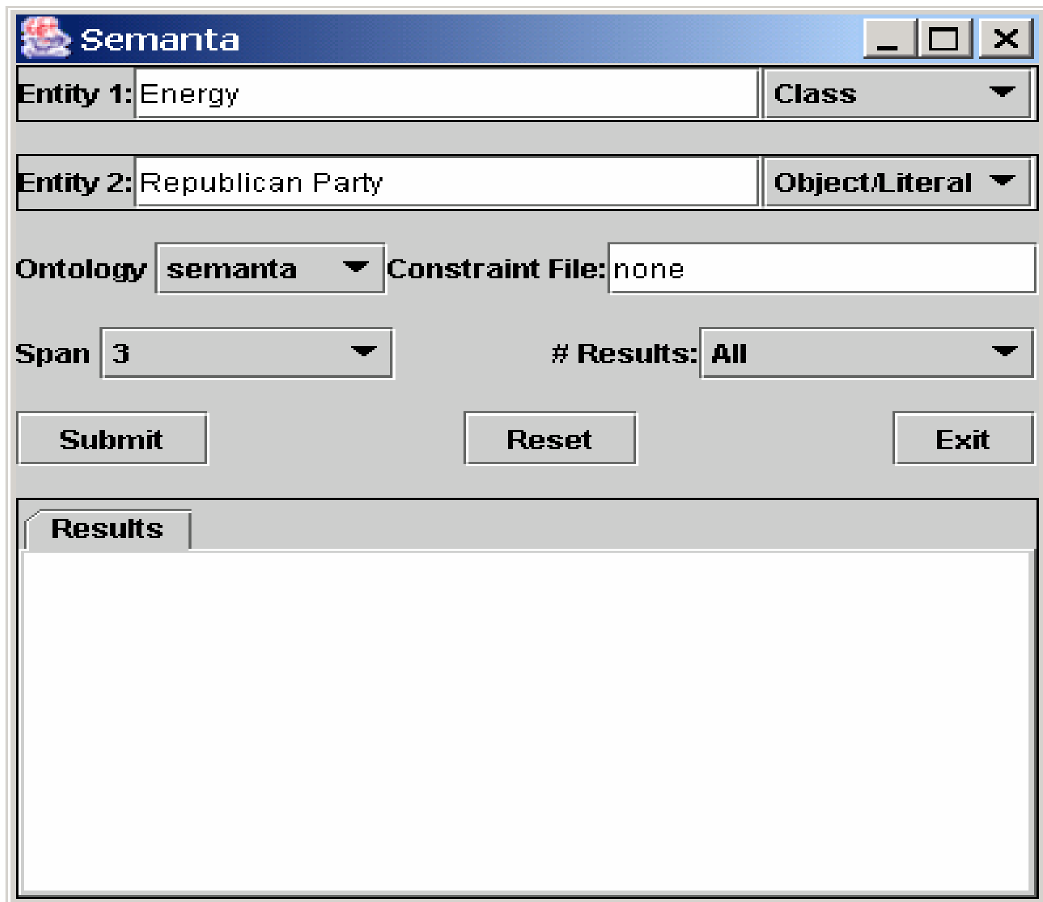
Semantic Link Queries

- Query

$< \underline{[O_i \mid o_i \mid O_i.A_i \mid o_i.a_i \mid x]}\ \underline{[R_i \mid x]}\ \underline{[O_i \mid o_i \mid O_i.A_i \mid o_i.a_i \mid x]}>$

- User-defined Constraints
  - Ontology constraints
    - Explicit inclusion/omission of ontologies
  - Semantic constraints
    - Relation Ontology
  - Span
    - To limit the search in Ontology layers
  - Number of results
    - Number of links between entities

Query Input Interface



Semantic Link Queries

Type	Example
O_i **x** O_k	1) *'University' x 'Music Groups'* 2) *'Mountain' x 'Casualties'*
O_i **x** o_k o_i **x** O_k	1) *'University' x 'R.E.M.'* 2) *'Nyiragongo' (Volcano) x 'Casualty'*
o_i **x** o_k	1) *'UGA' x 'R.E.M.'* 2) *'Bush' x 'Enron'*
$o_i.a_i$ **x** o_k	*'AlQeida.Afghanistan' x 'Baath Party'*
O_i R_i **x**	*'Person' 'positive-associate' x*
o_i R_i **x**	*'Halliburton Company' 'employs' x*

Entities Based Queries

Relations Based Queries

Entities Based Queries

- Finding links between any two entities (e_1, e_2)
- Entity: Class, Property, Literal
- Query types:
  - Type 1 : class/property, class/property
  - Type 2: class/property, literal
  - Type 3: literal, literal

Entities Based Queries (contd.)

- Type 1
  - Class/property, class/property

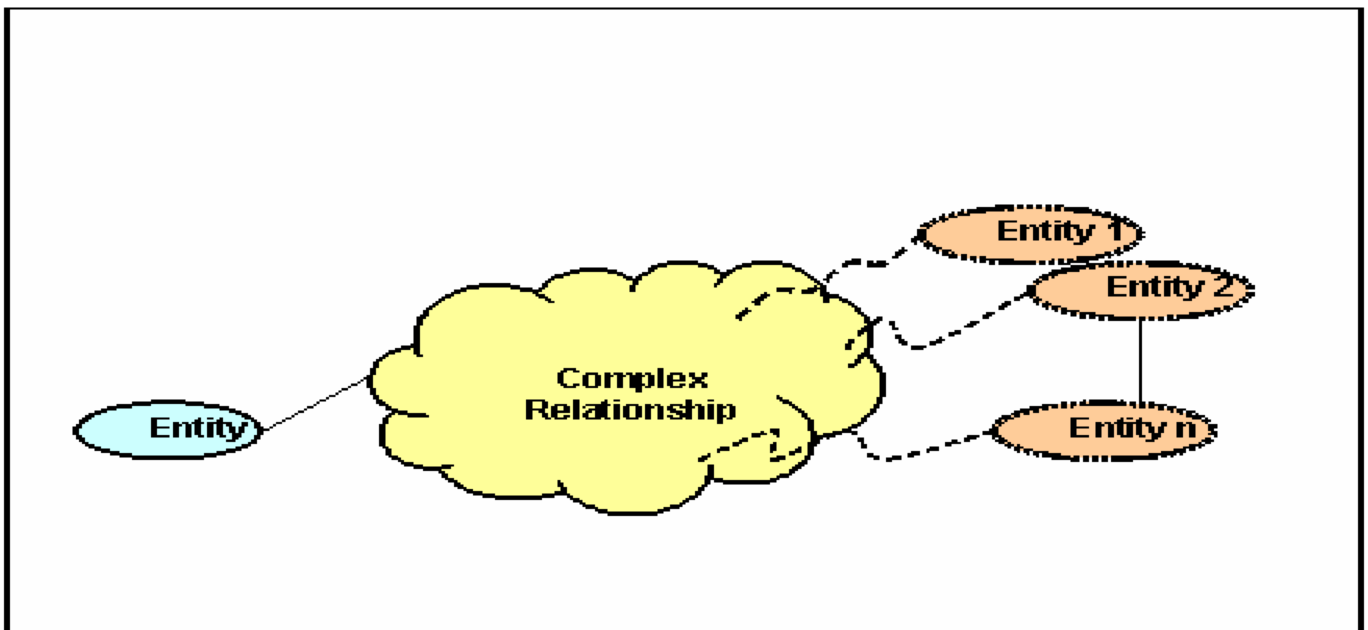
- Kinds of relationships
  - Class-attribute relationship
    - Address, city
  - Parent-child relationship
    - Industry <subclass-of> Telecom <subclass-of> Wireless Communication Services
  - Co-classes relationship
    - Event <funded-by> Organization, Project <funded-by> Organization
  - Linked classes relationship
    - Person <works-for> Company <funded-by> Organization

Entities Based Queries (contd.)

- Type 2:
  - Class/property, literal
  - Example:
    - Find links between the ‘Energy Sector’ and the ‘Republican Party of United States’
- Type 3:
  - Literal, literal
  - Object Base layer or text elements in Information Source layer
  - Example:
    - Find links between ‘Liming Cai’ and ‘Robert Robinson’

Relations Based Queries

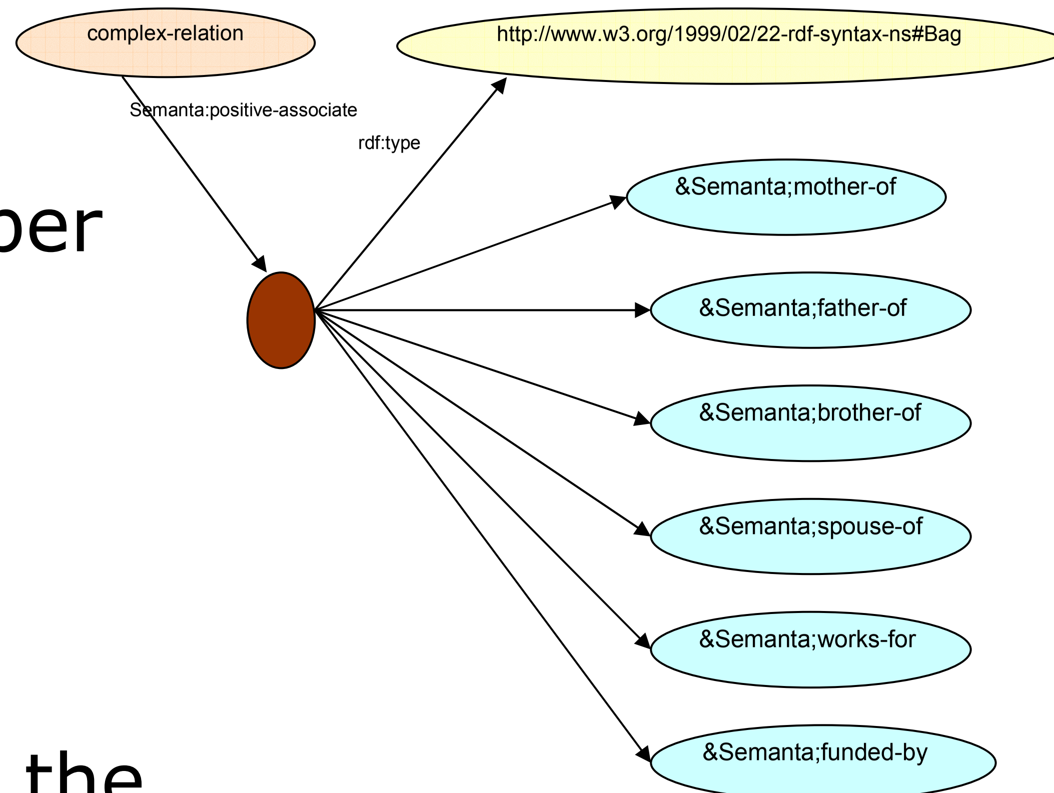
- Finding entities that are related to a given entity through a user-specified relationship



Relations Based Queries (contd.)

OR-Complex Relation

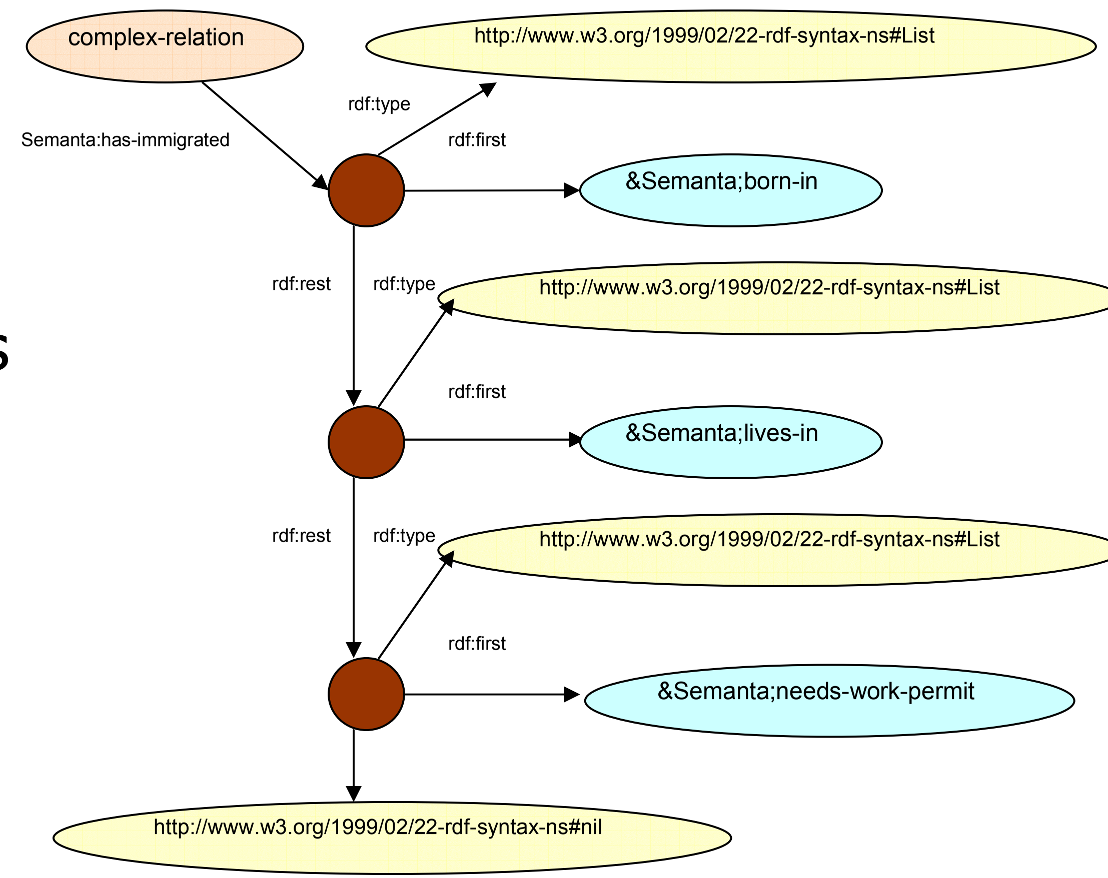
- A group of member relations
- No order among them
- Does not require the presence of all member relations



Relations Based Queries (contd.)

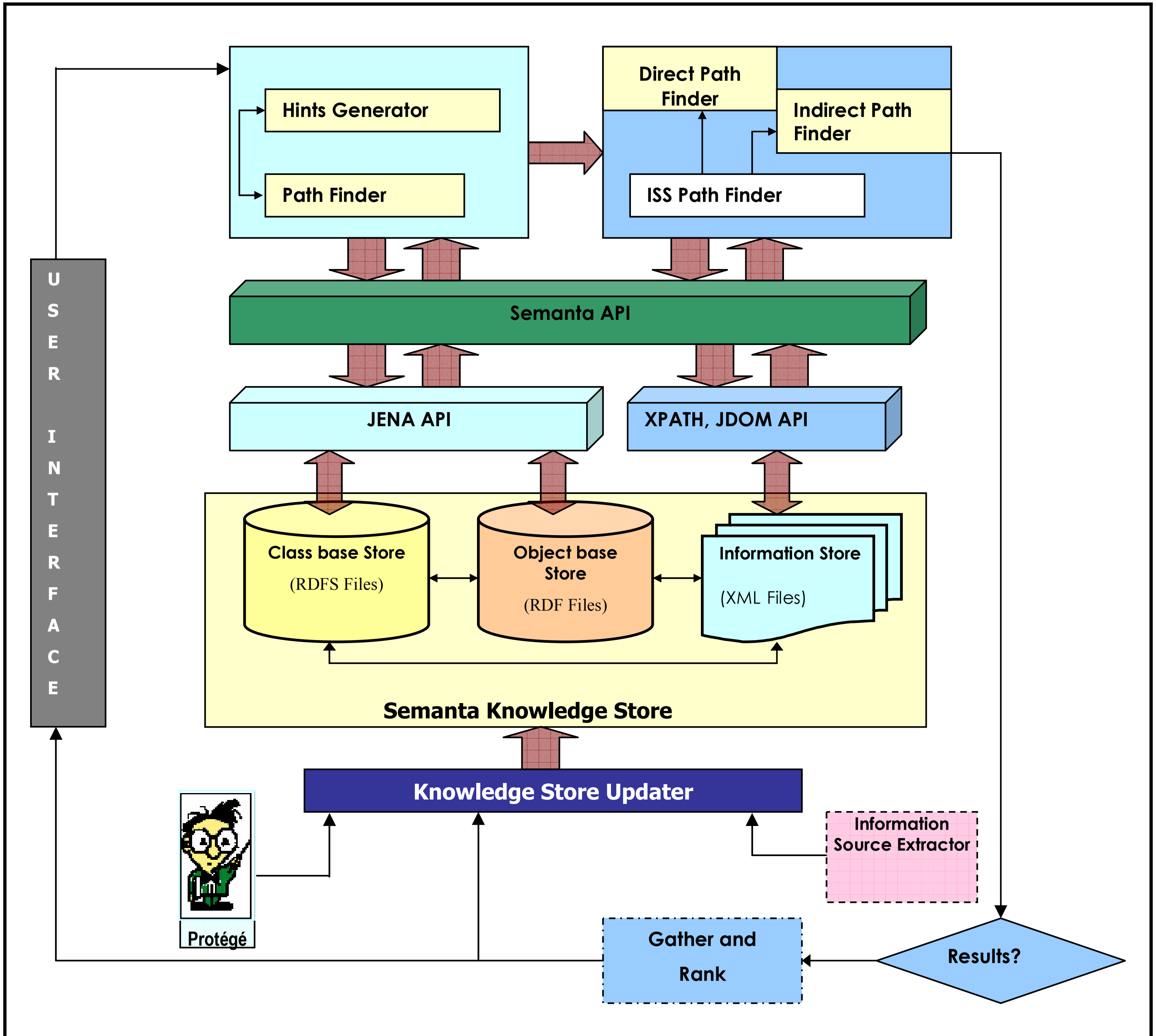
AND-Complex Relation

- All member relations will have to be present



System Architecture

System Architecture



Semanta API

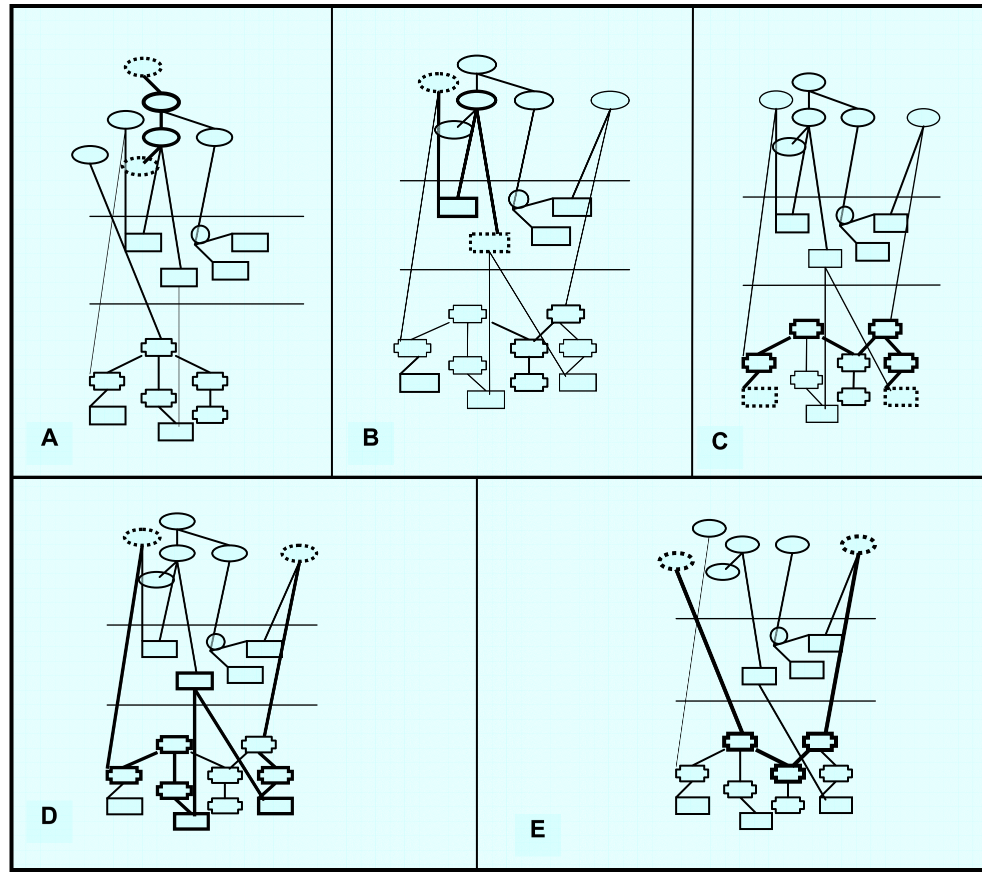
- CB Layer API
  - Over Jena 1.5.0, to access the RDFS files
  - Class Based API
  - Property Based API
- OB Layer API
  - Over Jena 1.5.0, to access the RDF files
  - Methods to get details of CB layer, given the OB layer details

Semanta API (contd.)

- IS Layer API
  - To access XML Documents
  - Stored via Apache Xindice
  - Uses Xpath API for accessing parts of the documents
  - JDOM, for accessing and manipulating XML documents

Searching the Ontology Layers

- Find paths within the Ontology layers (Path Finder)
- Generated hints for IS Layer processing (Hints Generator)



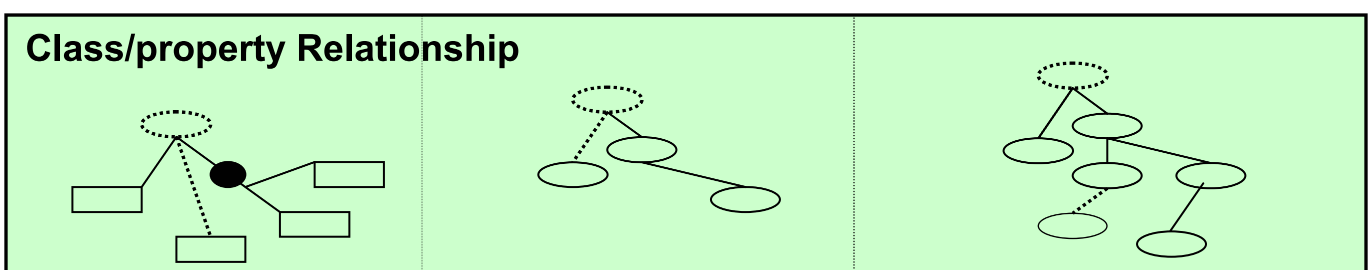
Path Finder

- Finding a path in the Ontology layers – finding a ‘semantic relationship’ between the entities
- Semantic relationship
  - Class-property relation
  - Property-property relation
  - Class-class relation

Path Finder (contd.)

Class-property Relationship

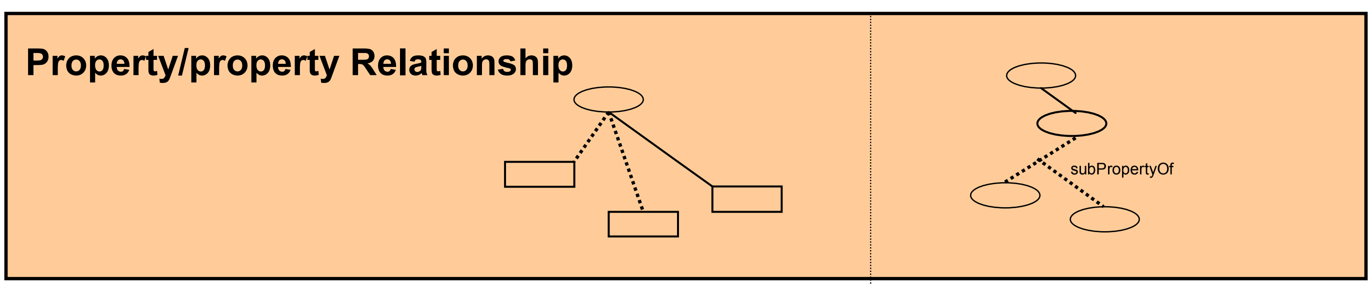
- Property is an attribute of the class
- Property (directly) links the class to another class
- Property is a transitive link to another class



Path Finder (contd.)

Property-property Relationship

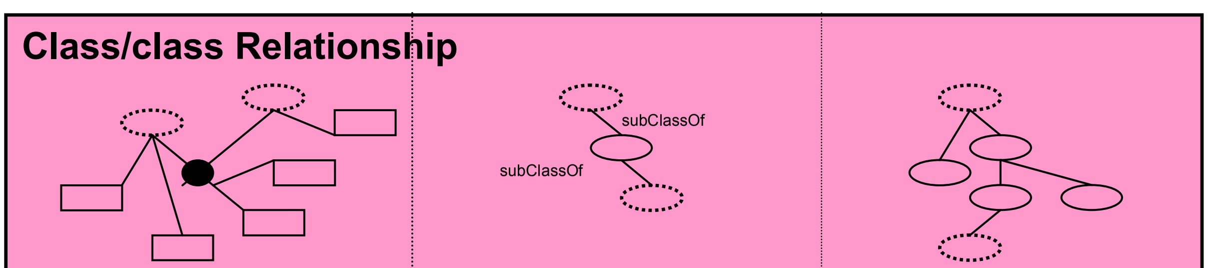
- Both properties belong to the same class, or the same instance of the class
- Hierarchical relationship between the properties



Path Finder (contd.)

Class-class Relationship

- Instance of the classes have property values that match
- Hierarchical relationship between the classes
- Classes are linked through property links



Path Finder (contd.)

- Start from entity e_1
  - Use Semanta API to look for e_2 in nodes connected through parent-child, class-attribute, co-classes, linked-classes relationship using Semanta API
- Direction is not significant
- Analogous to Breadth First Search (BFS)
  - Complexity - $O(n^{span})$
- Heuristics to improve search:
  - Directed BFS
  - Interactive Deepening

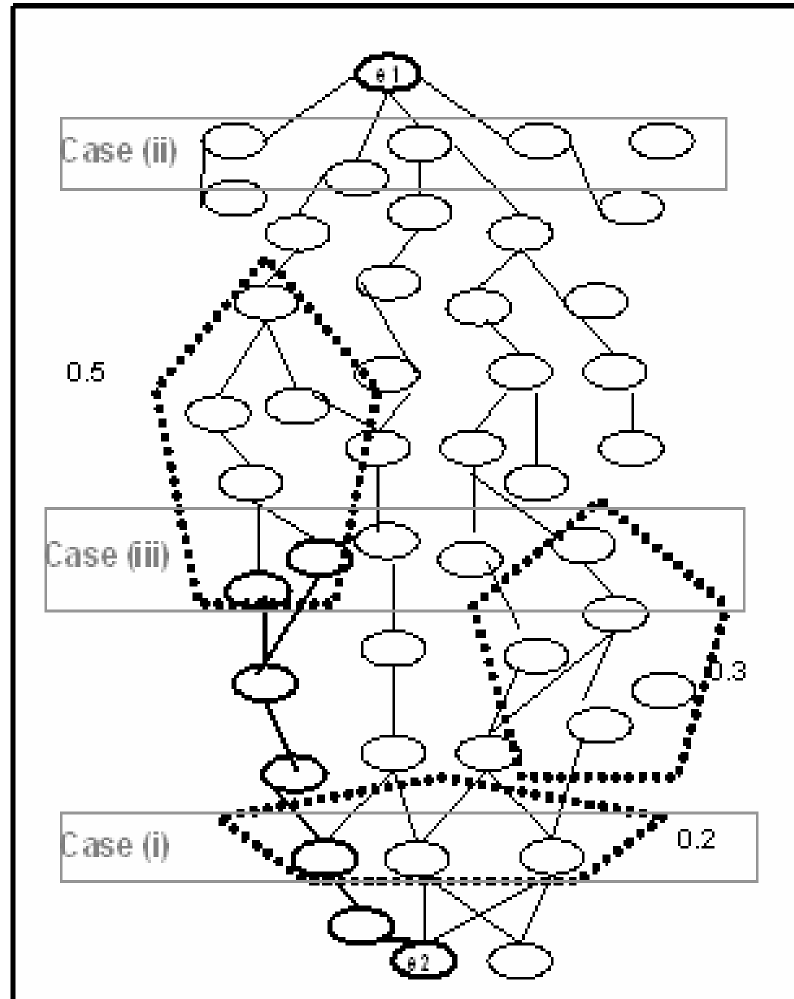
Directed BFS

Favor paths passing through user-defined domains (i.e., ontology constraints) and filter out other paths

P= [*window_size*, *span*]

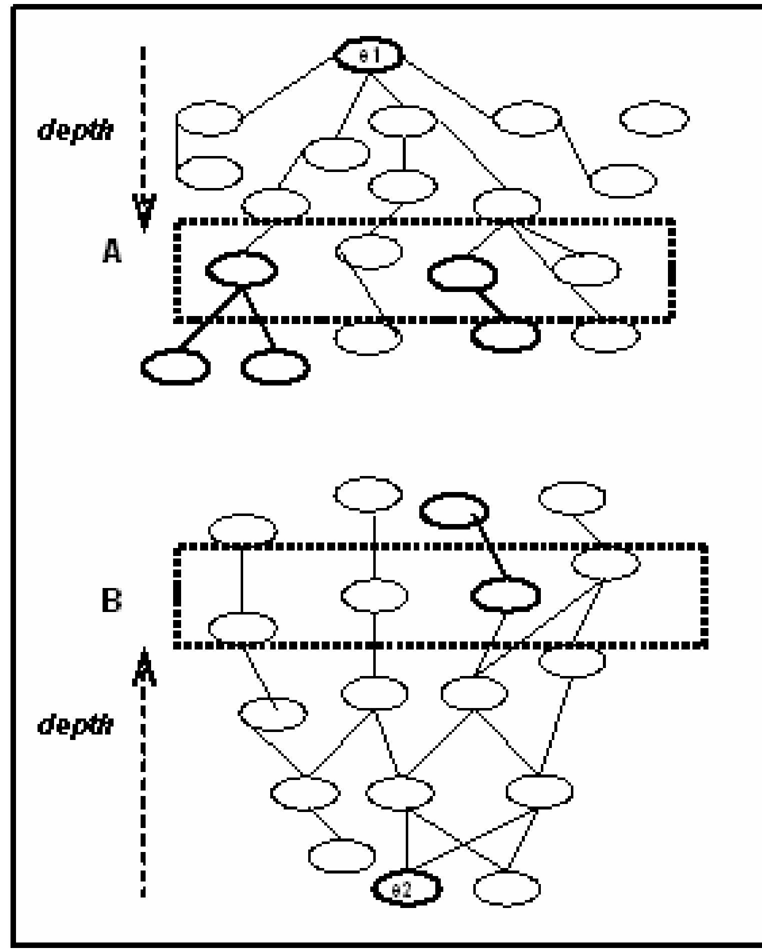
Nodes at level *l*:

1. Neighboring nodes belong to the same domain
2. None of the neighboring nodes belong to any specified domain
3. Neighboring nodes belong to multiple domains



Interactive Deepening

- User is able to control the search
- Depth and two-way search provides flexibility in interaction level and makes it easy to progress towards “meeting” paths respectively
- P= [*depth, span*]
- At *l=depth*
  - Existing paths are presented to the user.
  - User selects the nodes at this level, which s/he wishes to pursue.
  - Only the selected nodes are considered for finding subsequent paths.
  - Alternation (i.e., two-way search)



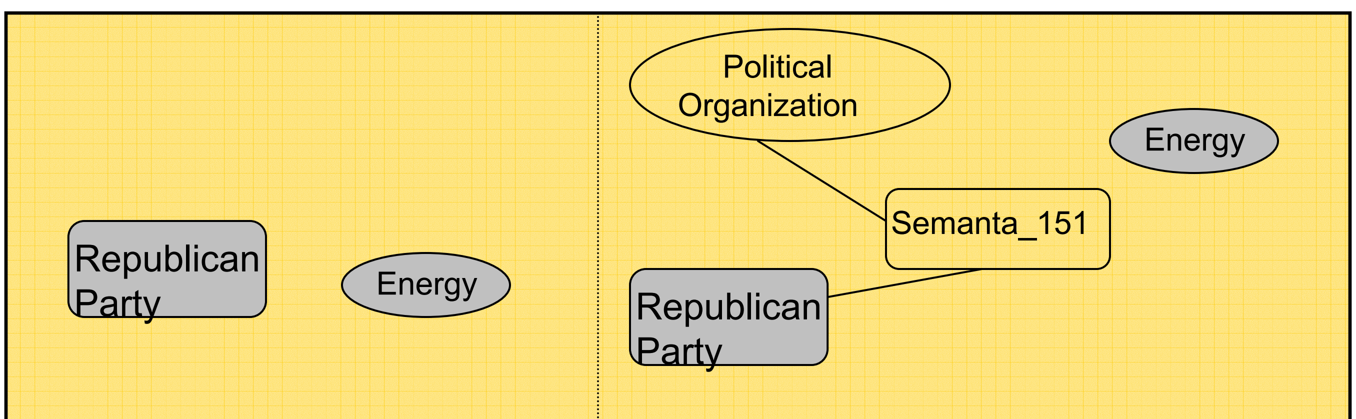
Traversing the Semantic Links

Finding the Semantic Links (Overall Picture)

1. Identify candidate nodes
2. Check for links in Ontology layers
3. Gather Hints from Ontology Layers
4. Generate XPath Queries
5. Check for links in Information Source layer
6. Present the results

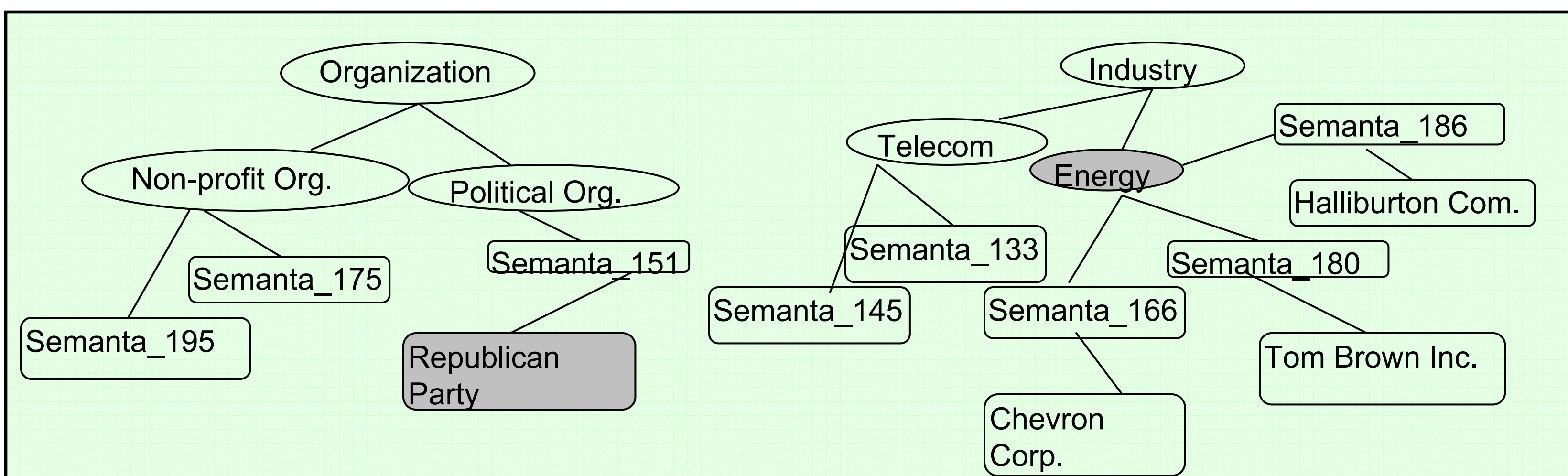
Finding the Semantic Links (contd.)

- Find links between 'Energy Sector' and 'Republican Party'
- e_1 = Energy, e_2 = Republican Party
- Identify category - Type 2 category
- Identify related nodes



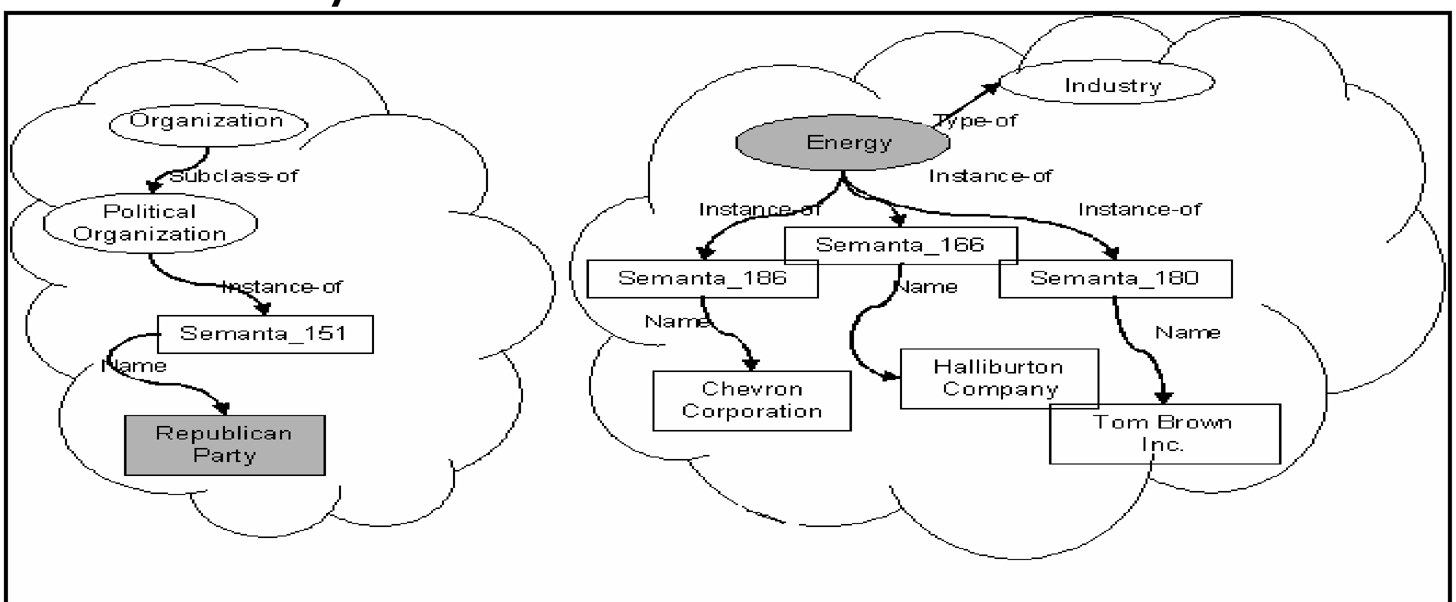
Paths in Ontology Layers

- Check for relations
  - Class-attribute
  - Parent-child
  - Co-classes
  - Linked classes



Generating Hints

- Hint:
  - Collection of class nodes, instance nodes and properties in the vicinity of an entity
- Gathered from the Ontology layers
  - Class nodes, Instance nodes, Properties
- Used to assist looking for links in Information Source Layer



Searching the Information Source Layer

- IS Layer is accessed
  - No links exist in the Ontology layers
  - Entities are not present in the Ontology layers
- Paths in IS Layer
  - Direct path
    - Parent-child or sibling relationship among entities
  - Indirect path
    - Parent-child or sibling relationship based on the hints
    - Matching patterns between documents

Paths in Information Source Layer

- Collect relevant documents
  - Generate XPath Queries

```
//*[normalize-space(.)=″Energy]//..//*[normalize-space(.)=″Halliburton
Company″]
//*[normalize-space(.)=″Energy]//..//*[normalize-space(.)=″Chevron
Corporation″]
//*[normalize-space(.)=″Energy]//..//*[normalize-space(.)=″Tom Brown
Inc.″]
//Industry[normalize-pace(.)=″Energy″]
//Political_Organization[normalize-space(.)=″Republican Party″]
```

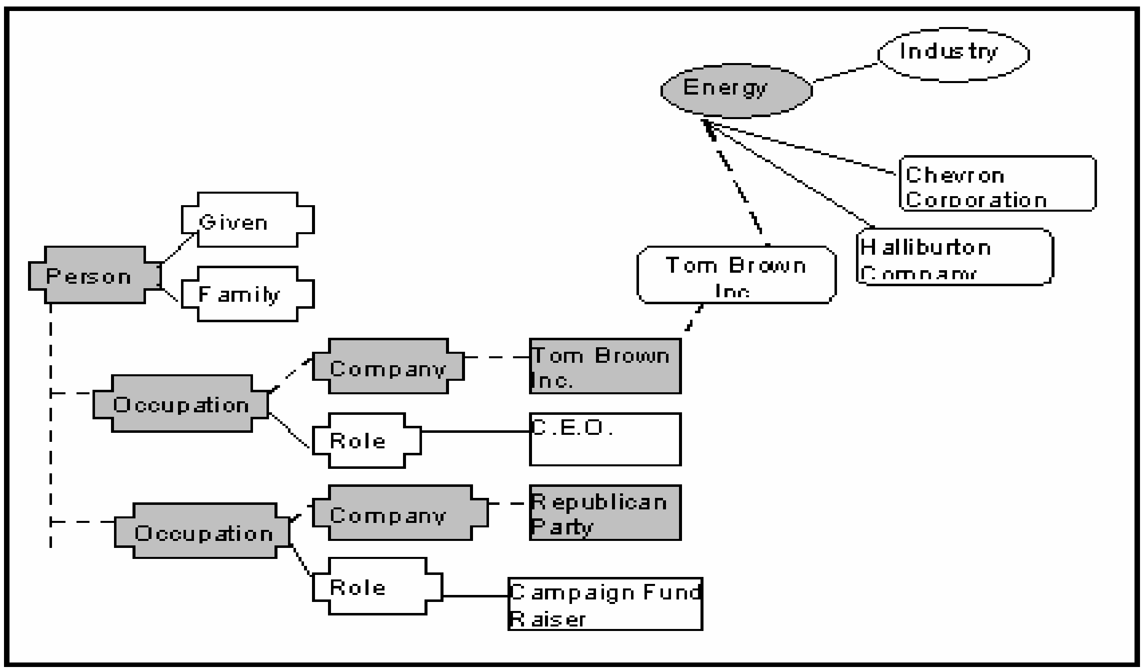
Direct Paths

- Paths based on parent-child, sibling relationship

```
<election year="2000" >
        <party="Republican Party">
                <contributor>
                        <company sector="Energy">
                          <name>Chevron Corporation</name>
                        </company>
                        <amount> 113,800</amount>
                </contributor>
        </party>
</election>
```

Indirect Paths

- Paths exist between elements of the hint-sets



Indirect Paths (contd.)

- Matching patterns between documents
- Pattern:
  - Identical tag and text elements along with the hierarchical structure

```
<person>
<name>
  <given> Robert </given>
  <family> Robinson </family>
</name>
<occupation>
  <profession>
   <industry> Education </industry>
   <company>Univ of Michigan<company>
  </profession>
  <profession>
   <industry> Education </industry>
   <company>Univ of Georgia</company>
   <role> Professor </role>
   <start_date>0/0/1984 </start_date>
  </profession>
</occupation>
```

```
<person>
<name>
  <given> Liming </given>
  <family> Cai </family>
</name>

<occupation>
 <profession>
  <industry> Education </industry>
  <company>Univ of Georgia</company>
  <role> Professor </role>
  <start_date> 0/0/2002</start_date>
 </profession>
</occupation>
```

Matching Pattern

```
              PERSON
                |
            Occupation
                |
            Profession
          |     |     |
     industry company role
  (Education)  (UGA)  (Professor)
```

Presenting Semantic Links

- User should be able to comprehend the results easily thereby aiding him/her in the end decision making
- More detail of each result should be available, where needed
- Information regarding the source from which results have been inferred should be available
- Summarizing results, based on parameters such as relationships, path-lengths, etc., should be present on request

Output Screenshot

Conclusions

- Three tier knowledge store
  - Class Base Layer, Object Base Layer, Information Source Layer
- Technologies of Semantic Web
  - RDFS, RDF, XML
- Classification of queries
  - Entities based queries
  - Relations based queries
- Semanta API and prototype Implementation

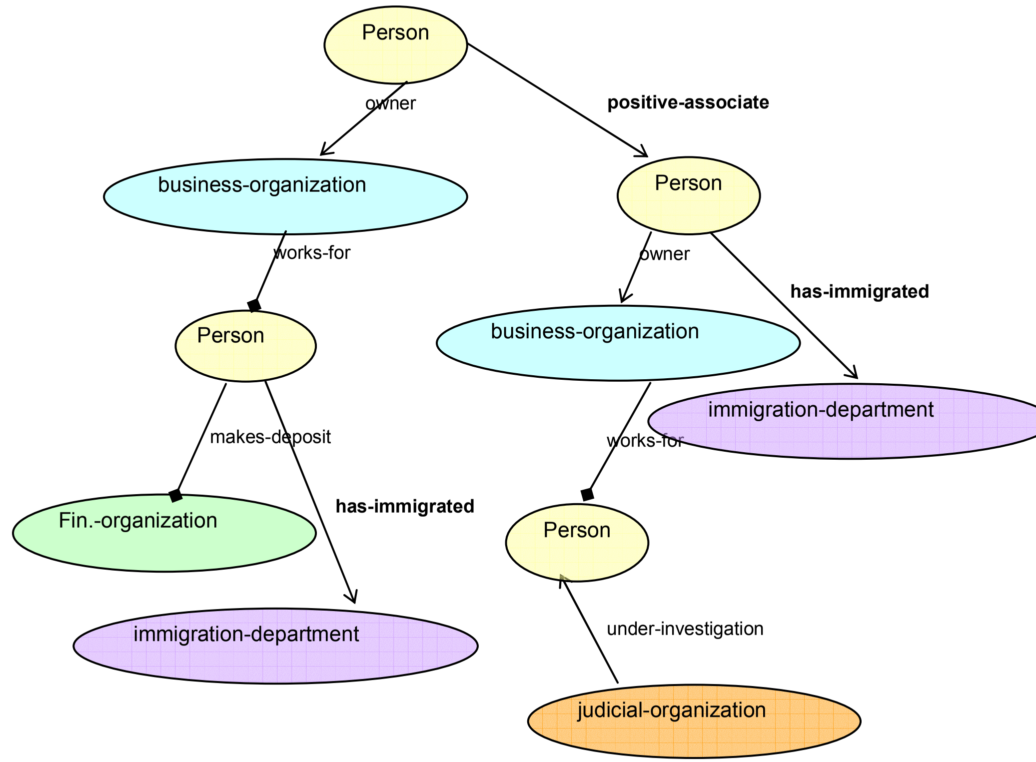
Future Work

- Template Relation
  - Enabling richer information analysis
- Visualization Tools
  - Selecting/omitting sections of ontologies or documents in Information Source layer
  - Presenting the process of finding paths to the user
- XML Schema
  - To enforce stronger binding between the Ontology Layers and Information Source Layer
- XPointer & XLink
  - To connect elements in multiple documents

Relations Based Queries (contd.)

Template Complex Relation

- Defined by a set of triplets
- Represent classes related by properties
- Attributes:
  - Multiplicity
  - Transitivity
  - Equivalence
  - Inverse
- Future research item



```
<person>
   <name>
      <first> Condoleezza </first>
      <last> Rice </last>
   </name>

   <birth>
      <date> … </date>
      <place> … </place>
   </birth>

   <occupation>
      <industry> Energy </industry>
      <company> Chevron Corporation </company>
      <role> Member, Board of Directors </role>
      <duration> …</duration>
   </occupation>
   ………………
   ………………
   <occupation>
      <industry> Finance </industry>
      <company> Charles Schwab Corporation </company>
            <role> Member, Board of Directors </role>
            <duration> … </duration>
   </occupation>
</person>
```