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Semantic Search With Self-Maintaining Classes

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Background

- Semantic search is all about *inferring* membership in query classes
 - Traditionally, semantic search has focused on class-subclass inference (subsumption)
 - Query: Aircraft
 - Match: MiG-23
 - Subclass of Fighter
 - Subclass of MilitaryAircraft
 - Subclass of Aircraft
- Most often, classes are enumerated through subsumption trees
- But class membership can also be inferred using
 - Logic (a class is the intersection of several other classes)
 - Properties (a class includes any x that has property y)
- In general, class membership descriptions can be complex
 - In OWL 2 these are called “Class Expressions”
 - In Description Logic these are called “Complex Concepts”

Class Expressions and Semantic Search

- Inferring class membership using class expressions is a powerful semantic search technique because:
 - **It provides a mechanism loosely analogous to database “views”**
 - Alternate ways of organizing information can be built on top of an existing ontology
 - Query classes do not have to reflect the subsumption hierarchy
 - Query classes do not have to be enumerated
- The inferred classes are self-maintaining because their membership automatically changes as the membership of underlying classes changes

A Case Study: Threats to Air Operations

- Problem: Air Force analysts searching image metadata for **“threats to air operations”**
- Currently, these searches are done using keywords
- But there may be many names for weapon systems:
 - NATO designations
 - Coalition partner names
 - Anglicized manufacturer names
- Having to include all these names in queries places a burden on the analyst
 - An ontology can keep track of all these names
 - This is an old technique: using a thesaurus to expand a query
- But even with only one term for each weapon, there are still a lot of weapons to list
- We would like to search for whole classes of threats

Searching for Threat Classes

- Threats to air operations include members of traditional weapons classes such as:
 - Aircraft
 - Missiles
 - Artillery
- But not all members of these traditional military classes are threats to air operations
 - Bombers are aircraft, but are not really a threat to an air operation
 - Ballistic missiles are not a threat
 - Surface-to-surface artillery is not a threat
- It is tempting to enumerate the threats to air operations
 - **What are all the types of Threats from the air ...**
 - **What are all the types of Threats from the surface ...**
- A better idea is to *infer* threats based on weapon properties

Inferring Threats from Properties

- Using OWL-DL we can say that the class of weapons that fires air-to-air missiles is a subclass of threats to air operations
- **We don't have to say (explicitly) what weapons are in that class**—they are inferred based on the property
- **We don't have to know (or care) where in the ontology such weapons exist**
- This technique allows us to cut across existing subsumption hierarchies and create alternate views of the knowledge
- In particular, we can create views that line up well with useful queries

Example: BM-21

- The BM-21 is a multiple-rocket launcher
 - Classic surface-to-surface artillery
- But adversaries modified the rockets
 - Used timed-fuzes
- And pointed the weapon straight up
 - Rockets become heavy flak



- The list of munitions that the BM-21 fires is updated to include these modified, now anti-aircraft rockets
- Since weapons that fire anti-aircraft artillery munitions are a **subclass of threats to air operations...**
 - The BM-21 *automatically* becomes a threat as soon as that property appears

OWL-DL Class Expression that Matches BM-21

```
<owl:Class rdf:about="#FunctionalAntiAircraftArtillery">
  <rdfs:subClassOf rdf:resource="#ThreatToAirOperations"/>

  <rdfs:subClassOf rdf:resource="#Artillery"/>
  <owl:equivalentClass>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#Fires"/>
      <owl:someValuesFrom rdf:resource="#AntiAircraftMunitions"/>
    </owl:Restriction>
  </owl:equivalentClass>
</owl:Class>
```

- This class expression defines—and *maintains*—a useful class
 - Prior to having anti-aircraft munitions, the BM-21 it is not a member of this class
 - Once the BM-21 fires anti-aircraft munitions it *automatically* becomes a member of this class

Case Study Summary

- Weapons are threats to air operations if they
 - Fire air-to-air missiles
 - Fire surface-to-air missiles
 - Fire anti-aircraft artillery munitions
 - Etc.
- We define a class expression for each of these
- **And make them all subclasses of “ThreatsToAirOperations”**
- Weapons automatically become members of the Threat class if they match the class expressions
- The class expressions automatically maintain class membership
- For scalable OWL-DL, we are implementing our semantic search using PelletDb (<http://clarkparsia.com/pelletdb/>)
 - A tight integration of Pellet and Oracle Semantic Technology

Generality of Search Using Self-Maintaining Classes

- This technique can be used in **any** domain where some query classes do not line up well with the subsumption hierarchy
- Some non-military possibilities:
 - Find me all the risky investments ...
 - Find me all the high-performance cars ...
 - Find me all the dangerous substances ...
 - ...

Questions?

QUESTIONS?

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