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## **Building Ontologies for GIS - Part 2**

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**Institute of Computer Science  
Academy of Sciences of the Czech Republic**

## **Building Ontologies for GIS – Part 2**

Zdeňka Linková, Radim Nedbal

Technical report No. 938

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Abstract:

Ontologies play an important role in knowledge representation. Among various fields, where ontologies can be useful, is the GIS data area. We consider data in a specific GIS domain and develop a new ontology. The result is described in this paper.

Keywords:

Ontology building, GIS

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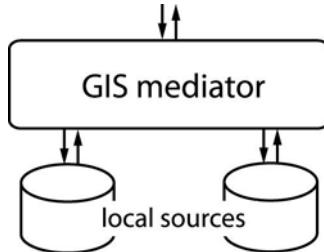
# 1 Introduction

Ontologies [1], [2] play an important role in information processing. As specifications of conceptualizations, they enable sharing terms across different applications and thereby they provide a way for application cooperation. Ontologies are basis for data sharing, data processing, and data integration. Similarly as in various fields that are based on knowledge representation, ontologies are useful also in geographical information processing. Geographical information system (GIS) [3], [4], [5], sophisticated system consisting of specialized software and hardware, is generally used to analyze and visualize spatio-temporal information. A part of GIS data domain was also our ontology research field. Our aim was to build an ontology for data used and provided by the integration system VirGIS [6], [7].

The paper is organized as follows: Section 2 gives a description of the VirGIS integration system and its data; Section 3 lists tools we used in our ontology development; and Section 4 presents final ontology we developed.

## 2 VirGIS data

VirGIS is a mediation platform that provides an integrated view of geographic data. The VirGIS system is composed of data sources and a mediator over them. The mediator, called a GIS mediator, provides a global virtual view allowing local sources to be accessed as one integrated source.



**Figure 1.** The integration system VirGIS

For querying, a client uses global terms and schema. The GIS mediator rewrites this query, poses it against local data sources, then composes final answer from local answers, and returns the result to the client.

Currently, VirGIS is implemented as an integration system of satellite images. Figure 2 illustrates local and global sources of VirGIS. Tables derived from SPOT and IKONOS catalogues and QUICK LOOK database are used as local sources.

SPOT		IKONOS		VIRGIS	
Attribute	Type	Attribute	Type	id	string
date_	Date	date_acqui	Date	name	string
sun_elev	numeric	sun_el	numeric	satid	string
satellite	string	satellite	string	date	Date
sat_id	numeric	sat_id	numeric	sun_elevation	numeric
key	string	key	string	url	string
the_geom.	Polygon	the_geom	Polygon	geom	Polygon

QUICK LOOK	
Attribute	Type
key	string
filename	string

**Figure 2.** Local and global satellite schemas

SPOT and IKONOS catalogues provide information about satellites; QUICK LOOK refers to a sample of small images that give an overview of satellite images. The role of the global source is played by the VirGIS database corresponding to a mediated schema. The VirGIS schema contains just one entity VIRGIS with the following attributes:

- string *id* (the primary key of a region captured)
- string *name* (the name of the satellite that the region is captured from)
- string *satid* (the satellite identifier)
- date *date* (the date when the region was captured)
- numeric *sun\_elevation* (the sun elevation when the region was captured)
- string *url* (the url where the region capture is saved)
- Polygon *geom* (the geometry of the region captured)

Starting from this schema description, our aim was a development of an ontology satisfying the VirGIS data semantics. It had to cover not only the global schema, but also the local ones and the relationships among them.

### 3 Used ontology language and tool

There are many tools and languages that can be employed as means for ontology development [8]. Among available ontology languages, we chose Web Ontology Language (OWL) [9]. One of the reasons was the fact that OWL is proposed to be the ontology language for the Semantic Web [1], [2]. The Semantic Web is a vision of the future Web in which information will be given explicit meaning, making it easier for machines to automatically process and integrate information available on the Web. The basis of the Semantic Web is XML (eXtensible Markup Language) [10]. On this basis, RDF (Resource Description Framework) [11] and RDF Schema [12], are built. These, XML based, fundamental tools are designated for specifying the meaning of information.

OWL, also a XML based language, being more expressive than XML Schema and RDF Schema, goes beyond these data models in its ability to represent machine processible content on the Web. OWL adds more vocabulary for describing properties and classes: among others, relations between classes (e.g. disjointness), cardinality (e.g. "exactly one"), equality, richer typing of properties, characteristics of properties (e.g. symmetry), and enumerated classes. A large number of organizations have been exploring the use of OWL, with many tools currently available. The Working Group of W3C [13] is maintaining a list of implementations and demonstrations [14]. Most of the systems currently using other ontology languages are now migrating to OWL.

In addition, a number of ontology language tools, such as the most widely used Protégé system [15], now provide OWL support. Protégé-2000 is an integrated software tool used by system developers and domain experts to develop ontologies and knowledge-based systems. With OWL Plug-in, Protégé provides support for editing in OWL. Moreover, the Protégé-2000 tool accesses all components through a uniform GUI (graphical user interface) whose top-level consists of overlapping tabs for compact presentation of different components and for convenient coediting between them. It is an open source software, seeming to be perspective from our point of view.

## 4 The VirGIS Ontology

The proposed ontology comes out of the data model described in Section 2. It is supposed the given satellite image databases (IKONOS, SPOT) are part of the VirGIS system. From the viewpoint of ontology, this is understood as implications:

$$\begin{aligned} \text{IKONOS(image)} &\rightarrow \text{VirGIS(image)}, \\ \text{SPOT(image)} &\rightarrow \text{VirGIS(image)}, \end{aligned}$$

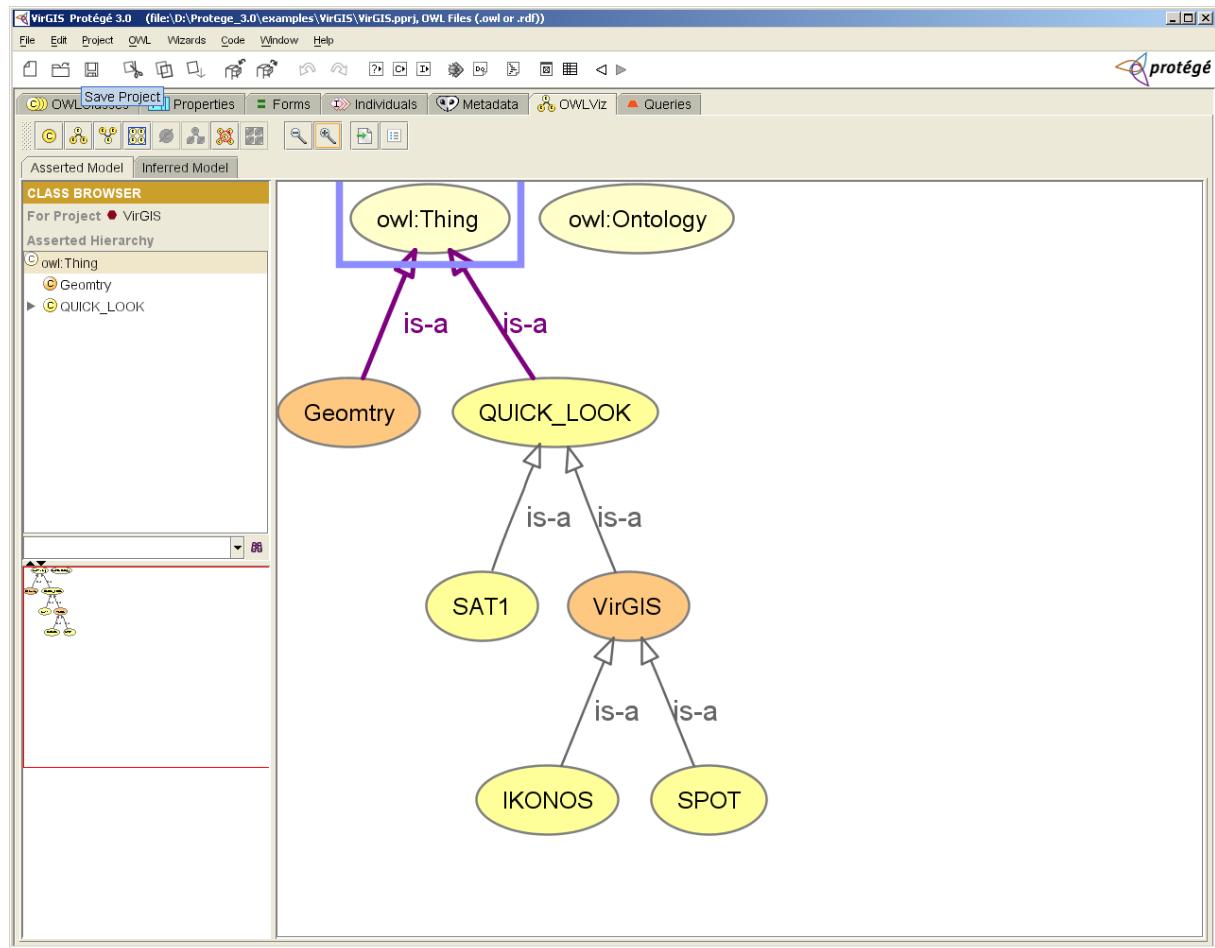
which, written by means of the predicate calculus, define semantic relationship of the above unary predicates. Furthermore, it is supposed that QUICK\_LOOK database contains small images corresponding to all VirGIS images:

$$\text{VirGIS(image)} \rightarrow \text{QUICK\_LOOK(image)}$$

and, possibly, also images from other sources (SAT1):

$$\text{SAT1(image)} \rightarrow \text{QUICK\_LOOK(image)}.$$

The ontology model is depicted in Figure 3. The Hasse diagram notation is employed to depict entity relationships. Each node corresponds to one class of objects (entities). There are two classes IKONOS and SPOT referring to local sources. A VirGIS class referring to the global mediated source is depicted as their superclass. This expresses that every image contained in IKONOS or SPOT database is also contained in VirGIS. Similarly, the VirGIS class is a subclass of a QUICK\_LOOK class. Formally, all the classes are subclasses of a unique superclass THING, inherent in QWL data model.



**Figure 3.** Our model designed in Protégé

In the model, there are two additional classes. The class SAT1 contains satellite images not integrated in VirGIS. A Geometry class contains geometric elements, designed for geometry type properties description purpose.

In QWL, a `owl:Class` construct is used for class description. The unary predicates are designated as classes (sets) and the implications mentioned above can be represented by means of the `rdfs:subClassOf` construct.

### **Example 1.:**

The relationship between SPOT and VirGIS classes is in OWL expressed ontology described as follows:

```
<owl:Class rdf:id="SPOT">
    <rdfs:subClassOf rdf:resource="#VirGIS" />
</owl:Class>
```

□

Note that corresponding data sources employ no common database schema. In particular, SPOT and IKONOS use semantically equivalent attributes without any common name convention. Similarly, VirGIS introduces its own identifiers for respective attributes. For instance, `date_` (SPOT), `date_acqui` (IKONOS) and `date` (VirGIS) represent semantically equivalent attributes. In VirGIS, this is solved by means of respective mapping. However, it could be expressed on ontology level. Considering the implication

$$\text{SPOT}(\text{image}) \rightarrow \text{VirGIS}(\text{image}),$$

it follows:

$$\text{date\_}(\text{image}, \text{DD/MM/YY}) \rightarrow \text{date}(\text{image}, \text{DD/MM/YY}),$$

which, written by means of the predicate calculus, defines semantic relationship between the binary predicates `date_` and `date`. The relations between other attributes are expressed analogically.

In OWL, the binary predicates are designated as properties and the implications can be represented by means of the `rdfs:subPropertyOf` construct.

### **Example 2.:**

The OWL transcription of the semantic relationship between `date_` and `date` is following:

```
<owl:DatatypeProperty rdf:about="#date_>
    <rdfs:subPropertyOf rdf:resource="#date" />
</owl:DatatypeProperty>
```

□

The complete OWL code of the described ontology is enclosed in the appendix.

## **5 Conclusion**

Ontologies are crucial in data description. According to this fact, a new ontology in GIS data area was developed. Particularly, this ontology describes sources and data in the VirGIS integration system. As other ontologies, also this one should evolve in order to follow the evolution of things it describes. In this case, it can, for instance, mean ontology enrichment along with adding new sources to VirGIS. Although ontologies are very powerful tools in data processing, there is still a lack of available and suitable ontologies in many areas. We believe that our approach and development can contribute to increase number of usable ontologies and can help in VirGIS data integration task.

## Acknowledgements

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# Appendix

```
<?xml version="1.0"?>
<rdf:RDF
    xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
    xmlns:owl="http://www.w3.org/2002/07/owl#"
    xmlns="http://www.owl-ontologies.com/unnamed.owl#"
    xml:base="http://www.owl-ontologies.com/unnamed.owl">
<owl:Ontology rdf:about="">

<owl:Class rdf:ID="SPOT">
    <owl:disjointWith>
        <owl:Class rdf:ID="IKONOS"/>
    </owl:disjointWith>
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#int">
                1</owl:cardinality>
            <owl:onProperty>
                <owl:DatatypeProperty rdf:ID="sun_elev"/>
            </owl:onProperty>
        </owl:Restriction>
    </rdfs:subClassOf>
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:onProperty>
                <owl:FunctionalProperty rdf:ID="sat_id"/>
            </owl:onProperty>
            <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#int">
                1</owl:cardinality>
        </owl:Restriction>
    </rdfs:subClassOf>
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:onProperty>
                <owl:FunctionalProperty rdf:ID="the_geom"/>
            </owl:onProperty>
            <owl:someValuesFrom>
                <owl:Class rdf:ID="Geomtry"/>
            </owl:someValuesFrom>
        </owl:Restriction>
    </rdfs:subClassOf>
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#int">
                1</owl:cardinality>
            <owl:onProperty>
                <owl:FunctionalProperty rdf:ID="satellite"/>
            </owl:onProperty>
        </owl:Restriction>
    </rdfs:subClassOf>
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#int">
                1</owl:cardinality>
            <owl:onProperty>
                <owl:DatatypeProperty rdf:ID="date_"/>
            </owl:onProperty>
        </owl:Restriction>
    </rdfs:subClassOf>
    <rdfs:subClassOf>
        <owl:Class rdf:ID="VirGIS"/>
    </rdfs:subClassOf>
</owl:Class>
```

```

<owl:Class rdf:about="#IKONOS">
  <owl:disjointWith rdf:resource="#SPOT"/>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty>
        <owl:DatatypeProperty rdf:ID="date_acqui"/>
      </owl:onProperty>
      <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#int">
        1</owl:cardinality>
    </owl:Restriction>
  </rdfs:subClassOf>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:someValuesFrom>
        <owl:Class rdf:about="#Geomtry"/>
      </owl:someValuesFrom>
      <owl:onProperty>
        <owl:FunctionalProperty rdf:about="#the_geom"/>
      </owl:onProperty>
    </owl:Restriction>
  </rdfs:subClassOf>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty>
        <owl:FunctionalProperty rdf:ID="sun_el"/>
      </owl:onProperty>
      <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#int">
        1</owl:cardinality>
    </owl:Restriction>
  </rdfs:subClassOf>
  <rdfs:subClassOf>
    <owl:Class rdf:about="#VirGIS"/>
  </rdfs:subClassOf>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty>
        <owl:FunctionalProperty rdf:about="#sat_id"/>
      </owl:onProperty>
      <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#int">
        1</owl:cardinality>
    </owl:Restriction>
  </rdfs:subClassOf>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty>
        <owl:FunctionalProperty rdf:about="#satellite"/>
      </owl:onProperty>
      <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#int">
        1</owl:cardinality>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>

<owl:Class rdf:ID="SAT1">
  <rdfs:subClassOf>
    <owl:Class rdf:ID="QUICK_LOOK"/>
  </rdfs:subClassOf>
</owl:Class>
<owl:Class rdf:about="#VirGIS">
  <owl:equivalentClass>
    <owl:Class>
      <owl:unionOf rdf:parseType="Collection">
        <owl:Class rdf:about="#SPOT"/>
        <owl:Class rdf:about="#IKONOS"/>
      </owl:unionOf>
    </owl:Class>
  </owl:equivalentClass>
</owl:Class>
<rdfs:subClassOf>

```

```

<owl:Restriction>
  <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#int">
    1</owl:cardinality>
    <owl:onProperty>
      <owl:DatatypeProperty rdf:ID="url"/>
    </owl:onProperty>
  </owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
  <owl:Restriction>
    <owl:onProperty>
      <owl:ObjectProperty rdf:ID="geom"/>
    </owl:onProperty>
    <owl:allValuesFrom>
      <owl:Class rdf:about="#Geomtry"/>
    </owl:allValuesFrom>
  </owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
  <owl:Restriction>
    <owl:onProperty>
      <owl:FunctionalProperty rdf:ID="name"/>
    </owl:onProperty>
    <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#int">
      1</owl:cardinality>
  </owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
  <owl:Restriction>
    <owl:onProperty>
      <owl:FunctionalProperty rdf:ID="sun_elevation"/>
    </owl:onProperty>
    <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#int">
      1</owl:cardinality>
  </owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
  <owl:Restriction>
    <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#int">
      1</owl:cardinality>
    <owl:onProperty>
      <owl:DatatypeProperty rdf:ID="id"/>
    </owl:onProperty>
  </owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
  <owl:Restriction>
    <owl:onProperty>
      <owl:FunctionalProperty rdf:ID="satid"/>
    </owl:onProperty>
    <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#int">
      1</owl:cardinality>
  </owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
  <owl:Restriction>
    <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#int">
      1</owl:cardinality>
    <owl:onProperty>
      <owl:DatatypeProperty rdf:ID="date"/>
    </owl:onProperty>
  </owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
  <owl:Restriction>
    <owl:someValuesFrom>
      <owl:Class rdf:about="#Geomtry"/>
    </owl:someValuesFrom>

```

```

<owl:onProperty>
    <owl:ObjectProperty rdf:about="#geom"/>
</owl:onProperty>
</owl:Restriction>
</rdfs:subClassOf>
<rdfs:subClassOf>
    <owl:Class rdf:about="#QUICK_LOOK"/>
</rdfs:subClassOf>
</owl:Class>

<owl:Class rdf:about="#Geomtry">
    <owl:equivalentClass>
        <owl:Class>
            <owl:oneOf rdf:parseType="Collection">
                <Geomtry rdf:ID="point"/>
                <Geomtry rdf:ID="linear"/>
                <Geomtry rdf:ID="triangular"/>
                <Geomtry rdf:ID="square"/>
                <Geomtry rdf:ID="circular"/>
                <Geomtry rdf:ID="oval"/>
            </owl:oneOf>
        </owl:Class>
    </owl:equivalentClass>
</owl:Class>

<owl:Class rdf:about="#QUICK_LOOK">
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:onProperty>
                <owl:FunctionalProperty rdf:ID="filename"/>
            </owl:onProperty>
            <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#int">
                1</owl:cardinality>
        </owl:Restriction>
    </rdfs:subClassOf>
    <rdfs:subClassOf rdf:resource="http://www.w3.org/2002/07/owl#Thing"/>
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:onProperty>
                <owl:FunctionalProperty rdf:ID="key"/>
            </owl:onProperty>
            <owl:cardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#int">
                1</owl:cardinality>
        </owl:Restriction>
    </rdfs:subClassOf>
</owl:Class>

<owl:ObjectProperty rdf:about="#geom">
    <rdfs:range rdf:resource="#Geomtry"/>
    <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#FunctionalProperty"/>
</owl:ObjectProperty>

<owl:DatatypeProperty rdf:about="#date">
    <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#date"/>
    <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#FunctionalProperty"/>
</owl:DatatypeProperty>

<owl:DatatypeProperty rdf:about="#date_>">
    <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#date"/>
    <rdfs:subPropertyOf rdf:resource="#date"/>
    <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#FunctionalProperty"/>
</owl:DatatypeProperty>

<owl:DatatypeProperty rdf:about="#date_acqui">
    <rdfs:subPropertyOf rdf:resource="#date"/>
    <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#date"/>
    <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#FunctionalProperty"/>
</owl:DatatypeProperty>

```

```

<owl:DatatypeProperty rdf:about="#id">
  <rdfs:subPropertyOf>
    <owl:FunctionalProperty rdf:about="#filename"/>
  </rdfs:subPropertyOf>
  <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#FunctionalProperty"/>
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:DatatypeProperty>

<owl:DatatypeProperty rdf:about="#sun_elev">
  <rdfs:subPropertyOf>
    <owl:FunctionalProperty rdf:about="#sun_elevation"/>
  </rdfs:subPropertyOf>
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#byte"/>
  <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#FunctionalProperty"/>
</owl:DatatypeProperty>

<owl:DatatypeProperty rdf:about="#url">
  <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#FunctionalProperty"/>
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:DatatypeProperty>

<owl:FunctionalProperty rdf:about="#key">
  <rdfs:subPropertyOf rdf:resource="#url"/>
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
  <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#DatatypeProperty"/>
</owl:FunctionalProperty>

<owl:FunctionalProperty rdf:about="#the_geom">
  <rdfs:subPropertyOf rdf:resource="#geom"/>
  <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#ObjectProperty"/>
  <rdfs:range rdf:resource="#Geomtry"/>
</owl:FunctionalProperty>

<owl:FunctionalProperty rdf:about="#sun_elevation">
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#byte"/>
  <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#DatatypeProperty"/>
</owl:FunctionalProperty>

<owl:FunctionalProperty rdf:about="#satellite">
  <rdfs:subPropertyOf>
    <owl:FunctionalProperty rdf:about="#name"/>
  </rdfs:subPropertyOf>
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
  <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#DatatypeProperty"/>
</owl:FunctionalProperty>

<owl:FunctionalProperty rdf:about="#sat_id">
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#positiveInteger"/>
  <rdfs:subPropertyOf>
    <owl:FunctionalProperty rdf:about="#satid"/>
  </rdfs:subPropertyOf>
  <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#DatatypeProperty"/>
</owl:FunctionalProperty>

<owl:FunctionalProperty rdf:about="#name">
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
  <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#DatatypeProperty"/>
</owl:FunctionalProperty>

<owl:FunctionalProperty rdf:about="#filename">
  <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#DatatypeProperty"/>
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:FunctionalProperty>

<owl:FunctionalProperty rdf:about="#sun_el">
  <rdfs:subPropertyOf rdf:resource="#sun_elevation"/>
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#byte"/>
  <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#DatatypeProperty"/>

```

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</owl:FunctionalProperty>

<owl:FunctionalProperty rdf:about="#satid">
  <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#DatatypeProperty"/>
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
</owl:FunctionalProperty>

<IKONOS rdf:ID="Ikonos2">
  <geom rdf:resource="#square"/>
  <date rdf:datatype="http://www.w3.org/2001/XMLSchema#date">
    2005-05-07</date>
</IKONOS>

<IKONOS rdf:ID="ikonos1">
  <date rdf:datatype="http://www.w3.org/2001/XMLSchema#date">
    2005-05-07</date>
</IKONOS>
</rdf:RDF>

<!-- Created with Protege (with OWL Plugin 1.3, Build 225.4)
http://protege.stanford.edu --&gt;</pre>
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