Knowledge Discovery Framework for the Virtual Observatory

Brian Thomas, Edward Shaya, Zenping Huang, Peter Teuben

Department of Astronomy, University of Maryland, College Park, MD, 20742

Abstract. We describe a framework that allows a scientist-user to easily query for information across all Virtual Observatory (VO) repositories and pull it back for analysis. This framework hides the gory details of meta-data remediation and data formatting from the user, allowing them to get on with search, retrieval and analysis of VO data as if they were drawn from a single source using a science based terminology rather than a data-centric one.

1. The problem with the VO

A key problem facing the Virtual Observatory (VO) is that the search for and fusion of VO data for scientific use still requires a human. The reason for this is easy to understand: the VO includes many heterogeneously, and incompletely (from a semantic standpoint) described data. Heterogeneous description arises from the differing database schema in which the data are held. UCD’s (see [1]) have been used to help solve semantic description of the data, however they only label the semantic meaning of the columns within tables, but they do not label overall content of the table, nor is there any understanding of how one table relates to another.

Thus the scientist-user of the VO must know the nature of the schema at a given repository, tailor their query to match it and then fuse/transform the data themselves, using both their knowledge of the field of astronomy, and the data at the given repositories to achieve the resulting dataset they desire to do their research.

This is not the manner in which most (or all!!) users of the VO would like to proceed to do research! Instead of thinking about the nuts and bolts of locating and downloading and combining the data they would prefer to ask a question of the VO like: “find stars with measured IR magnitudes which have been observed inside a spiral galaxy arm” and the machine will handle the dirty work of search and fusion.

2. The Solution: semantic interoperability

One means to solve this problem is to introduce a knowledge discovery framework around the existing data repository structure. This framework will provide what is called “semantic interoperability”, which may be defined as
A dynamic capability that allows a machine to infer, relate, interpret and classify the implicit meanings of digital content without human involvement.\(^1\)

An astronomical example of semantic interoperability: the machine is able to determine which (previously unidentified) astrometry data are about Pluto by referencing an ephemeris of Pluto’s orbit. Another example: the machine uses extant properties of spiral galaxy data such as I-band magnitude, inclination and rotational velocity to calculate a new property of distance using the Tully-Fisher equation.

3. Building a knowledge discovery framework

We have developed a design for a knowledge discovery framework for the VO. The framework consists of a semantic layer which allows mapping of semantic information to existing data, an ontological model of astronomical objects which includes details of the scientific relationships that exist between objects, and one or more tools to aid the human in utilizing the layer and ontology to discover, retrieve, and transform VO data.

Figure 1 provides an overview of this framework which comprises a semantic layer (VOORML, VO Object-Relational mapping layer), and a tool, Viper, which intermediates between the semantic layer and the human.

Below we provide brief detail of parts of the framework.

---

\(^1\)Paraphrased from the definition in [2]
3.1. **User tool : Viper**

This tool is designed to coordinate and aid the human in the tasks of discovery, retrieval and transformation of VO data. Viper consists of a number of major components including a semantic agent which coordinates inference made against the ontology, a data agent which coordinates search and retrieval requests to the semantic layer, and a transformer agent which acts on retrieved data to change it to the desired semantic state (as well as perform data fusion). A workflow manager coordinates activities between the respective agents.

Viper interacts with the human via a graphical workspace (similar to that shown in figure 2) in which objects (squares) are interrelated with known relationships (circles). A menu (not shown) allows the user to drop and drag either of these types of semantic term into the workspace, and the tool prevents illegal semantic combinations (as determined by the ontology). Because objects/relationships are defined in the ontology, Viper may be used to discover relationships the user is not aware of, and will then alter the workspace view appropriately to show them.

Viper, and the agents, are written in Java, and make use of Jena ([3]) and Pellet ([4]) to respectively represent, and reason on, the ontology.

3.2. **Ontology**

Our ontology presently consists of greater than 1000 objects related to astronomy. We include astronomical objects and phenomena as well as scientific relationships between them (such as Kepler’s Laws, the conversion between magnitude and an energy flux and so on). The ontology itself is serialized in OWL ([6]) and is realized as a number of sub-domains (each in a separate file) which include definitions of physical measurements/quantities, geometry, instruments, units, physics and statistics.

3.3. **Semantic layer : VOORML**

This software provides a mapping between the data in the repository and semantic terms which are described by the ontology (figure 3). In a nutshell, the layer uses a simple collection/quantity-based datamodel (see VOCatalog, [7]) to tag the semantic meaning of data at a repository. This model allows the layer to
understand how to map the parts of a query, framed in semantic terms, into a localized query (in SQL). The model also directs the layer on how to reassemble matched data back into the uniform, semantic model (again using VOCatalog) before it is returned. Presently this software only will work upon a JDBC interface, but in the future we hope to make the simple translation to ADQL so that SkyNodes ([8]) may be described as well. Finally, there is no reason this software need be deployed locally at the site of the repository.

4. Summary

It is impossible to describe the entire system in detail here. See our website ([9]) for further description and updates on progress of this work.

References

[1] UCD: Uniform Content Descriptor. [http://www.ivoa.net/Documents/latest/UCD.html](http://www.ivoa.net/Documents/latest/UCD.html)
[2] Pollock, J. T. & Hodgson, R. 2004, Adaptive Information, John Wiley & Sons, Inc., 3
[3] Jena: [http://jena.sourceforge.net](http://jena.sourceforge.net)
[4] Pellet: [http://www.mindswap.org/2003/pellet](http://www.mindswap.org/2003/pellet)
[5] OWL: Web Ontology Language. [http://www.w3.org/2004/OWL](http://www.w3.org/2004/OWL)
[6] Quantity/VOCatalog data model: Thomas et al., 2005, ADASS XV, poster. Paper available at [http://archive.astro.umd.edu/VOCollection](http://archive.astro.umd.edu/VOCollection)
[7] SkyNode: [http://www.ivoa.net/Documents/latest/SNI.html](http://www.ivoa.net/Documents/latest/SNI.html)
[8] UMD group website: [http://archive.astro.umd.edu](http://archive.astro.umd.edu)