1 Introduction

Some text ..

2 The IVOA

The International Virtual Observatory Alliance (IVOA) was formed in June 2002 with a mission to "facilitate the international coordination and collaboration necessary for the development and deployment of the tools, systems and organizational structures necessary to enable the international utilization of astronomical archives as an integrated and interoperating virtual observatory."

The work of the IVOA focuses on the development of standards, providing a forum for members to debate and agrees the technical standards that are needed to make the VO possible.

3 The VO

The Virtual Observatory (VO) is the realization of the IVOA vision of an *"an integrated and interoperating virtual observatory"*.

The operational VO itself is comprised of a distributed metadata registry, along with data discovery and data access services deployed at each participating institutes, which together enable the system to present a uniform mechanism for discovering and accessing data published in the virtual observatory, irrespective of where it is physically located.

3.1 The registry

The VO Registry provides the first layer of data discovery available in the virtual observatory. The individual registry services deployed at participating institutes work together to provide a shared repository for describing datasets, data access services and data processing services in a standard way.

The IVOA Registry Interfaces standard [1] defines *"the interfaces that support interactions between applications and registries as well as between the registries themselves"*.

The high level structure of the registry content is defined by a set of IVOA standards.

- IVOA Identifiers [2]
- Resource Metadata [3]

Combined with a set of lower level standards defining the detailed XML schemas for resource metadata.

- VOResource [4]
- VODataService [5]
- Simple Data Access Services [6]

3.2 Service registration

VOSI . . . and stuff . . .

3.3 Service metadata

registry metadata queries . . . and stuff . . .

3.4 Service footprint

registry footprint queries . . . and stuff . . .

HEALPix Multi-Order Coverage Map (MOC) [7]

3.5 Data access services

The VO DataAccess services can be categorised as two types of services.

A set of type specific data discovery servces which are designed to provide simple service interfaces for discovering and acessing data of a specific type.

- Simple Cone Search (SCS) [8]
- Simple Image Access (SIA) [9]
- Simple Spectral Access (SSA) [10]

- Simple Line Access (SLA) [11]

A tabular data access services for querying tabluar data using a common query derrived from SQL.

- Table Access Protocol (TAP) [12]
- Astronomy Data Query Language (ADQL) [13]

3.5.1 Simple Image Access

The Simple Image Access (SIA) protocol provides

> parameter based discovery of images and datacubes, querying the service(s) with a few well known kinds of queries that cover greater than 95% of use, and getting back easily parsed summary metadata about each available data product

The Simple Image Access (SIA) data discovery service provides support for the following use cases:

- find data that includes specified coordinates (e.g. for some object)
- find data in the circle with coordinate centre and radius
- find data in a range of longitude and latitude
- find data within a specified simple polygon (one region, no holes, less than half the sphere)
- find data containing a specified energy (e.g. wavelength) or in a specified range of energy values
- find data obtained at a specified time (e.g. including a time instant) or during a specified range of times
- find data obtained with specified polarization (Stokes) states
- find data within a specified range of spatial resolution
- find data within a specified range of field-of-view
- find data within a range of exposure (integration) time

The response from a successful SIA data discovery query is a VOTable containing instances of the ObsCore [14] data model.

Each row in the results corresponds to a data product that matches the search criteria and includes details of how to access the data products or how to request additional matadata.

3.5.2 Simple Spectral Access

The Simple Spectral Access (SSA) protocol is similar to the Simple Image Access (SIA) protocol.

The primary differences are the type of data searched for, and the set of query parameters.

> . . . discover and access one dimensional spectra . . . based on a general data model capable of describing most tabular spectrophotometric data, including time series and spectral energy distributions (SEDs) as well as 1-D spectra

3.5.3 Simple Line Access

The Simple Line Access (SLA) protocol is similar to the Simple Image Access (SIA) protocol.

The primary differences are the type of data searched for, and the set of query parameters.

> . . . retrieving spectral lines coming from various Spectral Line Data Collections . . . either observed or theoretical and will be typically used to identify emission or absorption features in astronomical spectra. . . . makes use of the Simple Spectral Line Data Model (SSLDM) [15] to characterize spectral lines through the use of uTypes [16]

3.5.4 Table Access Protocol

Table Access Protocol (TAP) is a generic protocol for accessing general table data, including astronomical catalogs as well as general database tables, with support for both synchronous and asynchronous queries.

Special support is provided for spatially indexed queries using the spatial extensions in ADQL.

A multi-position query capability permits queries against an arbitrarily large list of astronomical targets, providing a simple spatial cross-matching capability.

Deploying the same standard interface and query language across multiple sites means that cross-matching queries are possible by orchestrating a distributed query across multiple TAP services.

3.6 Data discovery example

The combination of data discoverry tools provided by the registry and the individual data access services working together enable the kind of *'whole sky'* data discovery queries that the virtual observatory is designed to provide.

As an example of how this works, the following sections will describe the IVOA standards and services involved in processing a data discovery query for a particular type of data, e.g. images, covering a particular region of the sky, in a particular wavelength e.g. infrared, visible light, radio or xray.

3.6.1 Service discovery

The first step in processing our *'whole sky'* search is to identify the set of services that contain the type of data we are looking for.

The example search is looking for images, so the first step is to query the registry to find services that offer a `ivo://ivoa.net/std/SIA` (SIA) capability.

The registry query can be refined by selecting services that contain data in the `optical` waveband.

The MOC coverage map for each service can be used to further filter the list of services to identify services that contain data in a particular region of the sky.

3.6.2 Data discovery

The next stage of the process is to send a SIA query to each of the SIA services returned from the service discovery stage.

SIA query can specify parameters for a particular wavelength and a particular region of the sky :

- `POS` The positional region
- `BAND` The the energy interval

The full list of SIA search parameters is given in appendix A.

Each SIA query returns a VOTable, each row of which contains metadata about an individual image.

The details of the VOTable field names, utypes, UCDs, and units to used in the response are defined in the [17] data model.

The final step is for the client software to aggregate the results from the individual SIA services and display them to the user.

The user selects which data products they are interested in, and the client software uses the information from the SIA results to download the individual data products and display them in the appropriate display tools.

3.7 Carbon density comparison use case

The following use case is based on a paper by Mitchard et al., (2014) [18] [19] comparing remote sensing data from the NASA Jet Propulsion Laboratory (Saatchi et al 2011) [20] [21] and the Woods Hole Research Center (Baccini et al 2012) [22] [23] with ground plot data from

RAINFOR [24] the Amazon Tree Diversity Network [25] TEAM (Tropical Ecology Assessment and Monitoring) [26] and PPBio (Brazilian Program for Biodiversity Research)

http://www.researchgate.net/publication/233379148$_The_Brazilian_Program_for_Biodiversity_Rese$

A SIA search parameters

The SIA search parameters include

- `POS` The positional region
- `BAND` The the energy interval
- `TIME` The the time interval
- `POL` The the polarization state

- `FOV` The the field of view
- `SPATRES` The the spatial resolution
- `EXPTIME` The the exposure time
- `COLLECTION` The name of the data collection that contains the data
- `FACILITY` The name of the facility where the data was acquired
- `INSTRUMENT` The name of the instrument with which the data was acquired
- `DPTYPE` The data type from the ObsCore [27] data model
- `CALIB` The calibration level
- `TARGET` The target name from the ObsCore [28] data model
- `TIMERES` The temporal resolution
- `SPECRP` The spectral resolving power
- `FORMAT` The data format

Notes

[1]http://www.ivoa.net/documents/RegistryInterface/

[2]http://www.ivoa.net/documents/latest/IDs.html

[3]http://www.ivoa.net/Documents/latest/RM.html

[4]http://www.ivoa.net/documents/latest/VOResource.html

[5]http://www.ivoa.net/documents/VODataService/

[6]http://www.ivoa.net/documents/SimpleDALRegExt/20131005/

[7]http://www.ivoa.net/documents/MOC/

[8]http://www.ivoa.net/documents/latest/ConeSearch.html

[9]http://www.ivoa.net/documents/SIA/

[10]http://www.ivoa.net/documents/SSA/

[11]http://www.ivoa.net/documents/SLAP/

[12]http://www.ivoa.net/Documents/TAP/

[13]http://www.ivoa.net/Documents/latest/ADQL.html

[14]http://www.ivoa.net/documents/ObsCore/

[15]http://www.ivoa.net/documents/SSLDM/

[16]http://www.ivoa.net/documents/Notes/UTypesUsage/index.html

[17]http://www.ivoa.net/documents/ObsCore/

[18]doi:10.1111/geb.12168

[19]http://onlinelibrary.wiley.com/doi/10.1111/geb.12168/abstract

[20]doi:10.1073/pnas.1019576108

[21]http://www.pnas.org/content/108/24/9899

[22]doi:10.1038/nclimate1354

[23]http://www.nature.com/nclimate/journal/v2/n3/full/nclimate1354.html

[24]http://www.rainfor.org/

[25]http://web.science.uu.nl/Amazon/ATDN/

[26]http://www.teamnetwork.org/

[27]http://www.ivoa.net/documents/ObsCore/

[28]http://www.ivoa.net/documents/ObsCore/