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Development of Japanese Virtual Observatory (JVO) : Experience on Interoperation with other Virtual Observatories and its Future Plan

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Abstract.

Virtual Observatries (VOs) are emerging research environment for astronomy, and 16 countries and regions have funded to develop their VOs based on international standard protocols for interoperability. National Astronomical Observatory of Japan (NAOJ) started its VO project (Japanese Virtual Observatory – JVO) in 2002, and developed its prototypes. We have succeeded to interoperate the latest JVO prototype system with VOs in the USA and Europe since December 2004. Some observed data by the Subaru telescope, ASCA satellite operated by the JAXA/ISAS, etc. are connected to the prototype. Successful interoperation of the JVO prototype with other VOs means that astronomers in the world will be able to utilize top-level data obtained by these telescopes from anywhere in the world at anytime.

System design of the JVO system, experiences during our development including problems of current standard protocols defined in the IVOA, and proposals to resolve these problems in the near future are described.

1. Introduction

The National Astronomical Observatory of Japan (NAOJ) operates the Subaru telescope in Hawaii and large radio telescopes in Nobeyama. All the observed data are digitally archived and are accessible via internet. The radio telescopes of Nobeyama produce about 1 TBytes per year, and the Subaru telescope outputs about 20 TBytes per year. NAOJ has joined the international project, ALMA, and it is foreseen that more than a few PBytes of data per year will be produced for the astronomy community.

Because astronomical objects radiate electromagnetic waves in wide frequency range, it has been recognized that multi-wavelength analyses are essential to understand physical and chemical behavior of galaxies, stars, planets and so on. The idea of the Virtual Observatory (VO) has recently appeared to resolve such situation, and the system has been developed in 16 countries and region around the world. These individual VO projects set up an alliance, the International Virtual Observatory Alliance (IVOA[1]), to standardize protocols for their interoperations.

JVO is designed to seamlessly access to multi-wavelength, federated databases and data analyses systems for astronomers through high speed network facility. The basic concept and a new query language to access to the distributed databases, JVO Query Language, are described in Ohishi et al. (2003).

Our past prototypes were not connected to other VOs, and it was desired to connect with other VO prototypes. Thus we have incorporated several standards that were developed in the IVOA, and have succeede to interoperate between VOs in the US/Europe and JVO. This paper describes its implementation and assessment of the performance.

2. Architecture of the Interoperable JVO system

Schematic diagram of the JVO system is shown in Figure 1. Its fundamental design is similar to our previous prototype systems (Ohishi et al. 2003; Shirasaki et al. 2004; Tanaka et al. 2004). Major differences are, e.g., adoption of the Web Services instead of the Grid Services, adoption of standardized protocols for the VOs (SIAP for images, SSAP for spectra, and ADQL for catalogs), and introduction of resource meta data exchange mechanism based on the OAI-PMH.

Queries issued by a user are sent from the user terminal to the JVO portal, and are parsed into single queries to appropriate servers that are found by consulting the registry. The parsed querying processes are executed by the scheduler, being passed to individual servers through appropriate protocol. The query results are sent back with the VOTable format.

Major database servers connected to this prototype are SuprimeCAM from Subaru telescope, ASCA (X-ray satellite) database operated by the Institute of Space and Astrocautical Science, Japan Aerospace Exploration Agency (JAXA /ISAS), and others. We succeeded to interoperate the JVO prototype with VOs in the North America (NVO, VO-Canada) and Europe (ESO, ESAC, Astro-

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

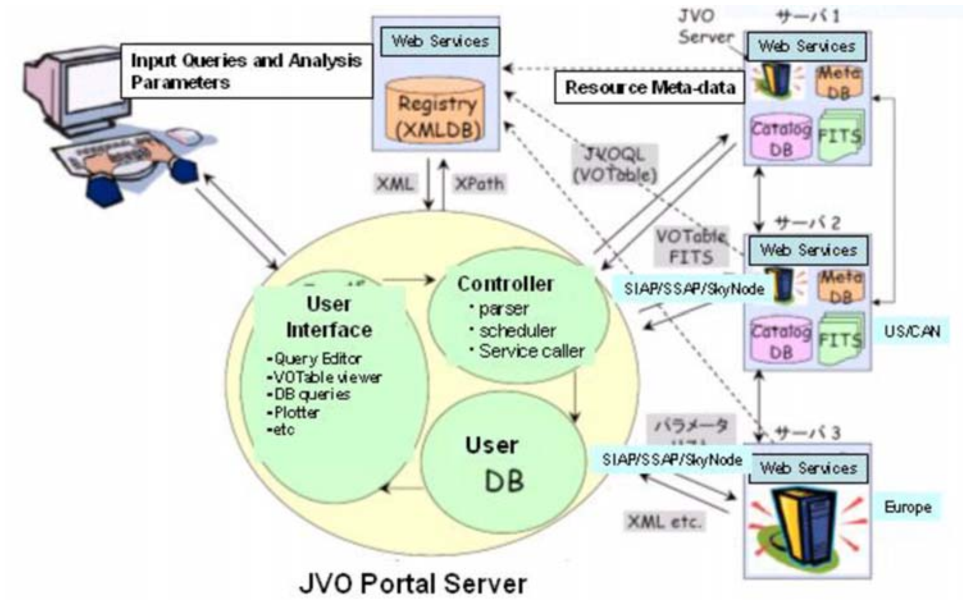

Figure 1. Architecture of Interoperable JVO system.

grid2, CDS) in December 2004, and more than 110 astronomical resoureces are available as of Ocotober 2005.

The protocols to access images, spectra and catalogs have been developled separately. Therefore it is necessary to prepare separate query interface to access to each resource. Astronomical researches may sometimes utilize images, spactra and catalogs simultaneously, and it is desirable to use an integrated query interface to make such queries easier. Shirasaki *et al.* (2004) proposed such an integrated query language by using the "virtual column" concept. We implemented the integrated query language interface to the interoperable JVO prototype, and succeeded to retrieve images/spectra/catalogs though a single interface. Further details are described in Shirasaki *et al.* (2005) in this volume.

3. Measurement of Access Time

We measured elapsed time to access data servers in the US. Table 1 summarizes "best" values obtained during our measurement. The elapsed times in our first prototype was around several tens of seconds to access database servers "within" our prototype system (Ohishi *et al* (2003). This was because previous prototype used the globus tool kit (GTK), and because a component in the globus tool kit had a fixed waiting time of 30 seconds. Since the GTK was designed to make collaborations for CPU-intensive jobs possible, we found the Web Services are more suitable for data-intensive jobs with less CPU times. This is clearly shown in Table 1 where elapsed times for queries to the US are less than 10 seconds. With such small elapsed times it would be possible for a user to interact with the VO systems to search for suitable data for her/his researchs.

Table 1. Sample Elapsed Time for Databases in the US.

band	Survey Name	Server	Time (second)
X-ray	Chandra	cda.harvard.edu	1.715
Infrared	2MASS	mercury.cacr.caltech.edu	3.536
Radio	VLA	adil.ncsa.uiuc.edu	7.115

4. Future Plan

Now it was established to access data servers via VO interfaces. Thus it is nesessary for astronomical researches to analyze obtained data on the VO environment. We have been designing a work flow language to access remotely located analysis engines. The work flow language will enable users not only data queries but data analyses through a single user interface. The details are described in a separate paper (Tanaka *et al.* 2005) in this volume. We plan to open to some volunteers to use and to evaluate the JVO system by March 2006.

Then we plan to implement Single-Sign-On mechanism for secure user access, and other standardized interfaces by the IVOA, and to disseminate standard VO interfaces to astronomy communities not only in Japan but in (East) Asian countries to further promote international collaborations. Such activity is crucial for the ALMA era that we expect to produce more than a few Peta Bytes per year.

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Tanaka, M. *et al.* 2004, will be given at a later time, [P.1.1.24]

Tanaka, M. *et al.* 2005, this volume, [P.107]