High Performance GIS and GEO Grid

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HPC for Societal Benefit Area

Understanding the Earth became to be more important.

- The 10-Year Implementation Plan for GEOSS (Global Earth Observation System of Systems) agreed upon at the Earth Observation Summit

Necessary to integrate Global Earth Observation data for understanding the Earth.

The GEO Grid is proposed as an E-Science infrastructure for understanding the Earth.

Federation of distributed and heterogeneous Earth observation data is the key to implement the Global Earth Observation System of Systems.

Work like a dog - before dying like a dog

© GEO
Icelandic Ash Cloud: Mantle-Crust-Glacier-Rivers Weather-Climate-Agriculture-Economy-Society
Global Observing System

Polar Orbiting Satellite

Geostationary Satellite

Satellite Images

Satellite Ground Station

Surface Station

Upper-Air Station

Automatic Station

Weather Radar

Weather Ship

Ocean Data Buoy

Aircraft

slide by courtesy of Dr. Bob Bishop, IESP
**Motivation: How can HPC-Grid-Cloud help?**

The GEO (Global Earth Observation) Grid is aiming at providing an *E-Science Infrastructure* for worldwide Earth Sciences communities to accelerate GEO sciences based on the concept that relevant data and computation are *virtually integrated* with a certain *access control* and ease-of-use interface those are enabled by a set of Grid and Web service technologies.

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**Satellite Data**
- Geo* Contents
- GIS data
- In-situ data

**Grid Technologies**
- Geosciences

**Applications**
- Environment Conservation
- Disaster mitigation

**Resources**
- GIS data

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AIST: OGF Gold sponsor (a founding member)
AIST: OGC Associate member (since 2007)

Project since 2004.11-

(Google Earth/Map 2005 Feb/Jun)
Objectives of GEO-* Grid

Help Geo-* scientists to understand
- Global warming, inventory of carbon dioxide
  - Kyoto protocol, environmental burden
- Alternate energy
  - Biomass
  - Wind-power generator network
- Harvest yield prediction/estimation
  - Weather, Soil, temperature, humidity, sunshine, etc.

Help decision makers to plan
- Hazard mitigation
  - Earthquake, Landslide, Flood, Volcano eruption, Tsunami
- Exploration of natural resources
  - Oil, natural gas, mineral

Unbeknown applications
- Games, Amusements, Personal geo-record/history, etc.
- Social science apps

Multi funded project
- National Data Archive
- METI – 100M/JPY (x5yrs)
- MEXT - 30M/JPY (x3yr)
- AIST – 75M/JPY(x3yr)
GEO Grid Enhanced Architecture

1. Explore/Search
2. Delivery
3. Process
4. Display

CS-W → WCS → WMS → WFS → WPS

Catalogue

data

resource pool

login
GEO Grid

Contents
- Satellite Imagery
- Geology archives
- Sensors

Software
- Basic service
- Web service

Support
- S/W packaging
- VO support

Full L0 ASTER on disk
MODIS on disk
(Japan & Thailand path)
Japan, SE Asia

Asian Flux, Field server
Security, Resource management, Job, data/storage, information

Web GIS, Workflow, U/I Portal

GEO Grid full/light
User account, Operation support
ASTER : Main content of AIST GEO Grid

- ASTER was developed by METI with AIST scientific & engineering supports
- Global land coverage of Digital Elevation Model of 15m spatial resolution
- Excellent geo-location accuracy
  - Easy to mosaic (or make a seamless image/DEM)
  - Easy to overlay to GIS data
- Powerful spectral analysis
  - VNIR 3 bands (+backward 1band)/SWIR 6 bands/TIR 5 bands
- 2000~
- Attached to Terra
  - MODIS has attached to the same satellite
Why “GRID”?

Data Grid capability
- large (>100TB) satellite imagery data
  - storage design, networking design
  - Next gen sensors require 10PB-
- loosely couple of a wide variety of geographically distributed data
  - meta data (access method, server location,), ontology,

Computing Grid capability
- on-demand generation of high level data products
  - adopt the most accurate geometric-, radiometric- and atmospheric-correction methods on-the-fly
- simulation jobs may consume computing resources
  - a “common” requirement of computing grid

Grid Basic Service
- compliance with owners’ access control policy of data/service
  - Grid Security Infrastructure – AuthN, AuthZ, Accounting
- complex workflow support in portals incl. data access, simulation execution, visualization, etc.
GEO Grid System Zones

Cloud Service zone
- SaaS: applications, libraries, hosting VM

Data Service zone
- Proprietary
- OGC WxS services
- Sat. Img. data archive ~ n PB

Laboratory zone
- Software development
- Application development

Google Service
- Map

Internet

Science Cloud GEOGrid. org

OGC WPS services
A Workflow example

“Disaster prevention and mitigation (Landslide)”

High resolution DEM provided from ASTER
Elevation, slope, aspect

Geology map (GSJ)

Geology
> rock type
> buffer

Landslide data
> true
> false

Geologic data (GML) via WFS of Geology DB

GSJ

NIED

Landslide susceptibility index map and its legend
XML (GML)

WCS

DEM (GeoTiff) via WCS of ASTER DB (OnDEM)

ASTER

Large scale Computer simulation using actual landslide DB

Early warning system based on Susceptibility map

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Conventional Approach (Landslide)

1. Data acquisition

- Request DEM
- Request CD-ROM
- Request FTP

2. Input data preparation using Image Processing & GIS software

- Convert Format
- Convert Projection
- Extract the Area of Interest

3. Number crunching Calculation

Many manual operations!
(e.g. data preprocessing)
multi-data policies
GEO Grid Approach (Landslide)

Available data
- DEM
- Geological Map
- Landslide Map

Training result
Estimation Result

Service
Registration
Metadata search

WCS

Download data via W*S
Input-data preprocessing

WFS

1. Download data via W*S
2. Input-data preprocessing
3. Calculation

Using free & open source software for geospatial

DEM

Geological Map

Landslide Map

VO Portal

Result

Data selection
Area of Interest
Parameters for ANN

Task

Download

Refer

Update

Refer
More sophisticated, more standard approach

Search

Key: pos, date, cloud, etc.

GEO Grid Search Service

On demand

CS-W

Metadata

Sat. Data

WMS

WMS/(WCS)

WMS: Web Map Service – jpeg, png
WCS: Web Coverage Service - Raster
Recently, Open Geospatial Consortium (OGC) launches a draft specification of Web Processing Service (WPS), originally named Geoprocessing Service.

A kind of the Remote Procedure Call model

The specified Web Processing Service provides client access to pre-programmed calculations and/or computation models that operate on spatially referenced data.

The result of request process are available to download for further analysis at user’s machine.
Cloud enabled Web Processing Service Server

**Execute Request**
http://wps.org/cgibin/wps.py?service=wps&version=0.4.0&request=execute&Identifier=shortestpath&Datainputs=cost,0,x1,596527,y1,4921298,x2,598173,y2,4923383&store=true&status=true
Stereo-matching software has often been used in generating a Digital Elevation Model (DEM) from a pair of satellite imagery data sets to compute height from parallax views using two photographic images.
Analysis of the program (outline) - core of DEM

Outline

- Compare image data from different sensors
  - Calculate correlative coefficient and identify spots.
  - Complement missing data and generate altitude.

Pre processing

- Input data
- Initialize structures

Main processing

- Template Matching
  - Compare two images and identify spots.
- Interpolation
  - Complement missing data
- Median Filtering
  - Remove noise
- Other filtering
- Output data

Post processing

- Free buffers

Outline:

- Pre Processing
- Main Processing
- Post Processing

Template matching

Template

Base Image

Search Coverage

Reference Image
What we have done

- Optimized Stereo-matching software on multicore processors
- Target architecture
  - Heterogeneous (Cell)
  - Homogeneous (Nehalem)
- How to optimize
  - Manual optimization (Cell)
  - OpenMP + Manual optimization (Nehalem)
- Platforms

<table>
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<tr>
<th>Platform</th>
<th>Processor</th>
<th>#CPU</th>
<th>memory</th>
<th>#core</th>
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<td>IBM PowerXCell 8i (3.2 GHz)</td>
<td>2</td>
<td>8GB</td>
<td>2 PPE + 16 SPE</td>
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<tr>
<td>HP Z800 Workstation</td>
<td>Intel Xeon X5500 (2.66 GHz)</td>
<td>2</td>
<td>4GB</td>
<td>8</td>
</tr>
</tbody>
</table>
Results of the optimization – possible acceleration in clouds

Exec. time of the original program on a single Nehalem core

- Reference: 455 sec
- Nehalem: 11.44 sec (x 39.8 speedup)
- Cell: 11.93 sec (x 38.1 speedup)

Many opportunities to improve performance by HPC
For interpreting objects in the earth surface easily by human eyes, natural color composite image is sometime needed.

- ASTER VNIR does not contain Blue band.
- Color and atmospheric correction technique developed by Lille University, France was implemented in GEO Grid to generate pseudo natural color ASTER images.
Haiti landscape after shake – created by PRISM + ASTER
Ground shaking due to an earthquake occurred in Suruga Bay, Japan, on August 11, 2009.
Summary

GEO Grid has done in

- Data Archives/services
  - ASTER all scenes in L1
  - PALSAR (part)
- AuthN, Group-AuthZ
  - VOMS, Tsukuba-GAMA
  - less management cost
- CS-W for Multiple data set
  - AIST CS-W, scalable
- Cloud based service
  - DEM, color coding
  - Earthquake, landslide, volcano

In progress

- Workflows – engine, language, tools
- Widgets design to build your own applications simply
- Digital Rights Management – water mark
- AuthZ in WMS, WFS, WCS, WPS
  - no clear strategic idea – whom to work with
- Full Cloud Service
  - easy adaptation
  - packaging
  - computing resource provider
- Google Earth integration – coming soon
GEO Cloud

See you again in SC10!