GOEN: Grid Computing in Geosciences &
SYNSEIS: a 3D Seismic Waveform Propagation Analysis Tool

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Outline

• GEON: Cyberinfrastructure for Geosciences
  – Grid technologies for distributed access to data and resources

• SYNSEIS
  – Part of the GEON infrastructure
  – An application for doing seismic analysis
  – Demo at the break
An Overview of GEON

• Designed to create a cyberinfrastructure for the Geosciences
• NSF Large ITR project – collaborative effort
• GEON is creating an IT infrastructure to “enable” interdisciplinary geoscience research -- not a group of researchers, but the entire community will benefit
• Project started in October 1, 2002 and will continue until September 30, 2007
Current GEON member institutions

Members

• Arizona State University
• Bryn Mawr College
• Penn State University
• Rice University
• San Diego State University
• San Diego Supercomputer Center / University of California, San Diego
• University of Arizona
• University of Idaho
• University of Missouri, Columbia
• University of Texas at El Paso
• University of Utah
• Virginia Tech
• UNAVCO, Inc.
• Digital Library for Earth System Education (DLESE)

Partners

• California Institute for Telecommunications and Information Technology (Cal-(IT)$^2$)
• Chronos
• CUAHSI
• ESRI
• Geological Survey of Canada
• Georeference Online
• IBM
• Kansas Geological Survey
• Lawrence Livermore National Laboratory
• U.S. Geological Survey (USGS)
• CIG

Other Affiliates

• Southern California Earthquake Center (SCEC), EarthScope, IRIS, NASA
GEOONgrid

Geological Survey of Canada

Livermore

ESRI

CUAHSI

Chronos

PoP node

5-node cluster

1TF cluster

Partner Projects

Partner services

Internet

Internet2

Other

NASA

USGS

GEOONgrid

CYBERINFRASTRUCTURE FOR THE GEOSCIENCES

www.geongrid.org
SYNSEIS

• A grid application that provides an unprecedented opportunity for seismologists and other earth science partners to compute and study 3D seismic records

• Built using a service-based architecture.
  – Provides users an easy-to-use GUI to access data, models and compute resources
  – Provides “connectors” (APIs) for developers should they choose to utilize any of its components in other applications.
Modeling earthquakes in 2D/3D environment to study the interior of the Earth.
The Architecture of SYNSEIS

User Access (via Web Browser)

GEONgrid Portal

Portlet User Interface
Client stubs

Job Submission/Monitoring and File Service

Operating and Queuing System on HPC resources

Data Model Service

Data Archives Service

Data Repository

Database

IRIS DMC

Cornell Map Server

HTTP

SOAP

SOAP

Grid Service

JDBC

IIOP/CORBA

Data Model Service

IRIS

DMC

HTTP
Mapping Service At Cornell U.
Events from IRIS DMC
Stations from IRIS DMC/SDSC
GEONgrid Portal

Welcome Dogan Seber!

PortalHome GEONsearch myGEON GEONscience System UserProfile MapIntegration

Home Rookies Test Bad Mid Atlantic Test Bed GEON SYNEIS Earth History NAVDAT CSS

SYNEIS 4.0

Connect to a station. Press Q to cancel.

Latitude ___ longitude ___

Access IRIS Data

Define Time Range

Begin Time 8 Sep 2004
End Time 0 Dec 2004

Retrieve Events
Retrieve Stations
Retrieve Waveforms
Show Waveform Window

Virtual Events & Stations

Drag and Drop an Earthquake or Station onto the map.

Earthquake
Lat: N/A
Long: N/A

Station
Lat: N/A
Long: N/A

Run Simulation

Run Simulation
Open Job Manager

SYNEIS 4.0

Event: 20041008T16:32:32.300Z

Latitude: 38.59
Longitude: 110.412
Depth: 0.698999988073071
Magnitude: 4.2

Station: BMN

Latitude: 40.4314
Longitude: 117.22059
Begin Time: 19970114000000 0000GMT
End Time: 20091231205698 0000GMT

GEON
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www.geongrid.org
Waveforms from IRIS DMC
The Architecture of SYNSEIS

User Access (via Web Browser)

Operating and Queuing System on HPC resources
Model behind SYNSEIS is E3D

- Shawn Larsen of Lawrence Livermore National Laboratory
- E3D is an explicit 2D/3D elastic finite-difference wave propagation code used for the modeling of seismic waves
  - 4th order accurate in space
  - 2nd order accurate in time
- It is based on the elastodynamic formulation of the wave equation on a staggered grid [Madariaga, 1976, BSSA; Virieux, 1986, Geophysics; Levander, 1988, Geophysics; Larsen and Harris, 1993, UCRL]
E3D more of the story

- Mostly C a few short Fortran routines
  - about 650 routines
  - 28,000 lines
- Has wrappers for various communications packages
  - Sun
  - MPI
E3D - SDSC changes

• “Portable-iz” it
  – Worked fine on LLNL resources
  – Idiosyncrasies in compilers can cause problems
  – Made in more compiler proof
  – Helps me understand the application
  – Runs using Intel, gcc (Intel/OSX), xlf/xlc (IBM)
  – Actually found some compiler bugs

• Volume output routines
  – MPI IO
  – Single processor does output
E3D - SDSC changes

• New boundary conditions
  – Surface on top and reflecting on sides and bottom
  – Add attenuation in the input earth model using variable Qp and Qs

• Create the earth model on the fly inside of E3D
  – Creation based on two layer files
  – Creation now done in parallel
  – We’re reading in large 3D volumes
E3D is only a component of SYNSEIS

• Could be supplemented with...
  – Pick your favorite simulation
What happens once we get to the HPC platform?

- Complete job description comes in as XML and processed by a perl script (1200 lines)
- Script
  - Creates E3D input
  - Parse out Moho.dat and Sediment.dat layer files
  - Build scripts to create the 3D earth models
    - R, P, S, Qp, Qs
  - Creates pbs batch script
  - Runs pbs batch script
E3D input file

grid q=1 n=323 l=410 m=250 dh=1 b=10
time dt=0.05  t=1500
source type=1 freq=0.225 amp=1.0E27 n=109 l=104 m=10
#source type=6 freq=0.225 amp=1.0E27 n=109 l=104 m=10
strike=SOURCE_STRIKE  dip=SOURCE_DIP rake=SOURCE_RAKE
vfile type=p file="earth" n1=0 n2=322 m1=0 m2=249 l1=0 l2=409
parallel nx=1 ny=2 nz=7
sac l=314 m=0 n=199 mode=1 file="station_1_sim_dat.1.bin"
vfile type=s file=earths n1=0 n2=322 m1=0 m2=249 l1=0 l2=409
vfile type=Qs file=earthqs Qf=0.225 n1=0 n2=322 m1=0 m2=249 l1=0 l2=409
vfile type=Qp file=earthqp Qf=0.225 n1=0 n2=322 m1=0 m2=249 l1=0 l2=409
vfile type=r file=earthr n1=0 n2=322 m1=0 m2=249 l1=0 l2=409
volume movie=10.0 mode=2 file="volume1"
image movie=10.0 m=0  mode=2  file="surface1"
What does batch script do?

- Optionally runs scripts to create R, P, S, Qp, Qs description files
- Run E3D
- Convert binary (SAC) traces to text
- Creates movies
  - x, y, z for surface, P potentials for volumes
  - Convert parallel volumes/surfaces to serial
    - (not required for MPI-IO)
  - Get slices (Volumes)
  - Convert slices or surface data to PNG
  - Convert PNG to AVI
Constant “Y” slice

P potential
Conclusions

• Using the Grid technology we were able to bring an extremely complex and cumbersome seismic data analysis procedure to a level that can be used by anyone efficiently and effectively

• SYNSEIS has allowed us to practice building distributed data and computational resources. We are now ready to expand such development efforts within the GEONgrid environment

• Demo to follow later.
Conclusions (2/2)

• SYNSEIS also has a high potential to be used in educational environments allowing students to experiment with data and make their own earthquakes.

• SYNSEIS has allowed us to practice building distributed data and computational resources. We are now ready to expand such development efforts within the GEONgrid environment.