Automating Real-time Seismic Analysis
Through Streaming and High Throughput Workflows

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Do we need seismic analysis?
USArray

A continental-scale Seismic Observatory

US Array TA (IRIS Service)

836 stations

394 stations have online data available

The development of reliable risk assessment methods for these hazards requires real-time analysis of seismic data.
So, how to efficiently process these data?
Experiment Timeline

Scientific Problem
Earth Science, Astronomy, Neuroinformatics, Bioinformatics, etc.

Analytical Solution

Computational Scripts
Shell scripts, Python, Matlab, etc.

Distributed Computing
Clusters, HPC, Cloud, Grid, etc.

Scientific Result
Models, Quality Control, Image Analysis, etc.

Automation
Workflows, MapReduce, etc.

Monitoring and Debug
Fault-tolerance, Provenance, etc.
What is involved in an experiment execution?
Why Scientific Workflows?

Automates complex, multi-stage processing pipelines

Enables parallel, distributed computations

Automatically executes data transfers

Reusable, aids reproducibility

Records how data was produced (provenance)

Handles failures with to provide reliability

Keeps track of data and files
Taking a closer look into a workflow...

Directed-acyclic graphs

- **job**
  - Command-line programs

- **dependency**
  - Usually data dependencies

- **split**
- **merge**
  - **pipeline**

Abstract workflow
Executable workflow
Optimizations
Storage constraints

http://pegasus.isi.edu
From the abstraction to execution!

- **stage-in job**: Transfers the workflow input data
- **stage-out job**: Transfers the workflow output data
- **registration job**: Registers the workflow output data

abstract workflow
executable workflow
optimizations
storage constraints

http://pegasus.isi.edu
Optimizing storage usage...

cleanup job
Removes unused data

http://pegasus.isi.edu
Workflow systems provide tools to generate the abstract workflow
Which Workflow Management System?
...and which model to use?

**task-oriented**

- **files**: data transfers via files
- **parallelism**: no concurrency
- **heterogeneous execution**: tasks can run in heterogeneous resources

**stream-based**

- **streams**: data transfers via memory or message
- **concurrency**: tasks run concurrently
- **homogeneous execution**: tasks should run in homogeneous resources

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Pegasus

http://pegasus.isi.edu
What does Pegasus provide?

**Automation**
- Automates pipeline executions
- Parallel, distributed computations
- Automatically executes data transfers
- Heterogeneous resources
- Task-oriented model
- Application is seen as a black box

**Debug**
- Workflow execution and job performance metrics
- Set of debugging tools to unveil issues
- Real-time monitoring, graphs, provenance

**Recovery**
- Job failure detection
-Checkpoint Files
- Job Retry
- Rescue DAGs

**Optimization**
- Job clustering
- Data cleanup
...and dispel4py?

**Automation**
Automates pipeline executions
Concurrent, distributed computations
Stream-based model

**Mapping**
Sequential
Multiprocessing (shared memory)
Distributed memory, message passing (MPI)
Distributed Real-time (Apache Storm)
Apache Spark (Prototype)

**Workflow Composition**
Python Library
Grouping (all-to-all, all-to-one, one-to-all)

**Optimization**
Multiple streams (in/out)
Avoids I/O (shared memory or message passing)
Asterism greatly simplifies the effort required to develop data-intensive applications that run across multiple heterogeneous resources distributed in the wide area.
Where to run scientific workflows?
There are several possible configurations…

Workflow Engine

Submit host (e.g., user’s laptop)

Compute Site

Shared filesystem

Input data site
Data staging site
Output data site

Typically most HPC sites

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Cloud Computing

High-scalable object storages

Workflow Engine

submit host
(e.g., user’s laptop)

Compute Site

Staging Site

object storage

Input data site
Data staging site
Output data site

Typical cloud computing deployment (Amazon S3, Google Storage)
Grid Computing

submit host
(e.g., user's laptop)

Workflow Engine

Compute Site

Typical OSG sites
Open Science Grid

local data management
And yes... you can mix everything!
How do we use Asterism to automate seismic analysis?
Seismic Ambient Noise Cross-Correlation

Preprocesses and cross-correlates traces (sequences of measurements of acceleration in three dimensions) from multiple seismic stations (IRIS database)

Phase 1: data preparation using statistics for extracting information from the noise

Phase 2: compute correlation, identifying the time for signals to travel between stations. Infers properties of the intervening rock
Seismic Ambient Noise Cross-Correlation

- Distributed computation framework for event stream processing
- Designed for massive scalability, supports fault-tolerance with a “fail fast, auto restart” approach to processes
- Rich array of available spouts specialized for receiving data from all types of sources
- Hadoop of real-time processing, very scalable

Pegasus

http://pegasus.isi.edu
Seismic workflow execution

input data (~150MB)

IRIS database (stations)

data transfers between sites performed by Pegasus

Phase 1
Compute site A
(MPI-based)

Phase 2
Compute site B
(Apache Storm)

submit host
(e.g., user’s laptop)

output data (~40GB)
Southern California Earthquake Center’s CyberShake

Builders ask seismologists: What will the peak ground motion be at my new building in the next 50 years?

Seismologists answer this question using Probabilistic Seismic Hazard Analysis (PSHA)

286 sites, 4 models each workflow has 420,000 tasks
A few more workflow features...
Performance, why not improve it? 

clustered job
Groups small jobs together to improve performance

task
small granularity

workflow restructuring
workflow reduction
hierarchical workflows
pegasus-mpi-cluster

http://pegasus.isi.edu
What about **data reuse**?

Jobs which output data is already available are pruned from the DAG
Handling large-scale workflows

Sub-workflow

Sub-workflow

Recursion ends when workflow with only compute jobs is encountered

Workflow restructuring

Workflow reduction

Hierarchical workflows

pegasus-mpi-cluster

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Running fine-grained workflows on HPC systems...

submit host (e.g., user’s laptop)

workflow wrapped as an MPI job

Allows sub-graphs of a Pegasus workflow to be submitted as monolithic jobs to remote resources

HPC System

Master (rank 0)

worker
rank1

rankn-1

workflow restructuring
workflow reduction
hierarchical workflows

pegasus-mpi-cluster
Pegasus
Automate, recover, and debug scientific computations.

Get Started

Pegasus Website
http://pegasus.isi.edu

Users Mailing List
pegasus-users@isi.edu

Support
pegasus-support@isi.edu

HipChat
Thank You

Questions?

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