Persistent Archives, Digital Libraries, and Data Grids
(Storage Resource Broker - SRB)

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Michael Wan
Reagan W. Moore
(sekar, mwan, moore)@sdsc.edu
Topics

• Data management systems
  – Generic distributed data management solutions

• Data Grids
  – Distributed data management infrastructure

• Digital Libraries
  – Information management infrastructure

• Persistent Archives
  – Technology management infrastructure
Knowledge Based Data Management

- Ingest Services
  - Relationships Between Attributes
  - Attributes About Data
  - Digital Entities

- Management
  - RDF
  - XML
  - AIP/HDF
  - Data Repository

- Access Services
  - Knowledge Repository
  - Information Repository
  - Data Repository

- (Rule-based Management)
  - RDF Repository
  - XML Repository
  - AIP/HDF Repository

- (Information-based Management)
  - Rule-based Query
  - Attribute-based Query
  - Byte-based Access

Attributes

Knowledge

Information

Data

Digital Entities

AIP/HDF

Byte-based Access
Data Management Systems

• Ingestion
  – Data collecting - Sensor systems, object ring buffers and portals
  – Data organization - Collections, manage data context

• Management
  – Data sharing - Data grids, manage heterogeneity
  – Data preservation - Persistent archives, manage technology evolution

• Access
  – Data publication - Digital libraries, support discovery
  – Data analysis - Processing pipelines, manage knowledge extraction
Knowledge Based Data Management

Knowledge

Information

Data

Ingest Services

Management

Access Services

- Relationships
- Knowledge
- Rule-based

Sensor Systems

- Persistent Archives
- Digital Libraries
- Collections
- Data Grids

- AIP/HDF
- Storage Repository
- By Access

- XML DTD

Digital Lib.

RDF

OWL

AIP/HDF

Posix I/O

Analysis Pipelines
Data Grid

• Support data sharing between institutions
  – Discover relevant data without knowing the file name
  – Access data without knowing the storage location or storage access protocol
  – Retrieve data using your preferred API
• Organize distributed data in a collection hierarchy
• Manage latency in wide-area-networks
• Manage PetaBytes of data and hundreds of millions of files
Digital Library

• Provide curation services
  – Organization, description, and management of data
  – Support schema extension

• Provide access services
  – Discovery, browsing, presentation, and manipulation of data

• Federate semantics across collections
  – Digital library crosswalks
Persistent Archive

- Minimize risk of data loss
  - Preserve collections for hundreds of years
  - Replicate data and metadata
- Support archival processes
  - Appraisal, accession, arrangement, description, preservation, and access
- Manage technology evolution while preserving integrity of data
Generic Infrastructure

- SDSC developed the Storage Resource Broker (SRB) to support access to distributed data
  - Effort started in 1996 as a DARPA funded project
  - Now support over 30 national/international projects

- Development team of 11 staff is led by
  - Michael Wan, data management systems
  - Arcot Rajasekar, information management systems
SDSC SRB Team

- Reagan Moore
- Michael Wan
- Arcot Rajasekar
- Wayne Schroeder
- Arun Jagatheesan
- Charlie Cowart
- Lucas Gilbert
- George Kremenek
- Sheau-Yen Chen
- Bing Zhu
- Roman Olschanowsky (BIRN)
- Vicky Rowley (BIRN)
- Marcio Faerman (SCEC)
- Antoine De Torcy (IN2P3)
- Students & emeritus
  - Erik Vandekieft
  - Reena Mathew
  - Xi (Cynthia) Sheng
  - Allen Ding
  - Grace Lin
  - Qiao Xin
  - Daniel Moore
  - Ethan Chen
  - Jon Weinburg
# SRB Collections at SDSC

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** Does not cover data brokered by SRB spaces administered outside SDSC.
Does not cover databases; covers only files stored in file systems and archival storage systems
Does not cover shadow-linked directories
## SRB Collections at SDSC

### As of 3/3/2004

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**TOTAL**

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Preservation

- Extract a digital record from its creation environment and import into a preservation environment
- Preserve provenance information about creation of the digital record
- Manage evolution of the preservation environment (continued import onto new technology)
Persistent Archives

• When migrate from an old technology to a new technology, both versions are available.
  – Extract files from old environment and load into new environment

• Abstraction mechanisms used for federation across space can be used to manage migration over time

• Persistent archives can be built on data grid infrastructure
Preservation Processes

• Appraisal
  – Determine what should be preserved

• Accession
  – Controlled import of Submission Information Packages

• Description
  – Creation of preservation metadata

• Arrangement
  – Organization of submitted material

• Preservation
  – Storage of Archival Information Packages

• Access
  – Delivery of Dissemination Information Packages
Preservation Challenges

• Build infrastructure independent solution
• Access to storage systems
• Persistent naming convention
• Manage preservation metadata
• Assure data and metadata consistency
• Authentication and authorization
• Assure ability to display and manipulate
Storage of Data

• Manage data distributed across multiple storage systems
  – Replication of data for fault tolerance
  – Replication of data for disaster recovery

• Manage data residing in heterogeneous storage systems
  – Support new storage systems while moving data from old storage systems
Storage Repository Virtualization

User Application

Archive  Database  File System
Storage Repository Virtualization

Remote operations
- Unix file system
- Latency management
- Procedures
- Transformations
- Third party transfer
- Filtering
- Queries

User Application

Common set of operations for interacting with every type of storage repository

Q Archive

Database

File System
Persistent Naming Convention

- Logical name space for location-independent identifiers for digital entities
  - Organized as collection hierarchy
  - Attributes mapped to logical name space
    - Attributed managed in a database

- Types of administrative metadata
  - Physical location of file
  - Owner, size, creation time, update time
  - Access controls
Data Virtualization

User Application

- Archive at SDSC
- Database at U Md
- File System at NARA
Data Virtualization

Logical name space
  Location independent identifier
  Persistent identifier

Collection owned data
  Access controls
  Audit trails
  Checksums
  Descriptive metadata

Inter-realm authentication
  Single sign-on system

User Application

Common naming convention and set of attributes for describing digital entities

Archive at SDSC
Database At U Md
File System at U Texas
Preservation Metadata

• Descriptive information
  – Logical name for material
  – Discovery attributes
  – Provenance attributes
  – Authenticity attributes

• Administrative information
  – Location where data is stored
  – Location of replicas

• Integrity information
  – Audit trails
  – Access controls
  – Checksums
Data Grid Approach

Preservation Processes

Multiple Storage Repositories

Directory, Metadata

Metadata servers

Secure, Reliable File I/O

Collection metadata
File metadata
Descriptive metadata
State Information

Data
Data Grid Approach

- Preservation Processes
- Client Abstraction
  - Secure, Reliable File I/O
  - Directory, Metadata
- Storage Repository Abstraction
  - Multiple Storage Repositories
- Information Repository Abstraction
  - Metadata servers
- Collection organization
  - File status, creation
  - Descriptive metadata
- Data
  - State Information
Data Grid Approach

- Preservation Processes
- Client Abstraction
  - Latency Management
  - Persistent objects
  - Parallel I/O
  - Discovery
  - Containers
  - Authenticity
  - Replicas

- Storage Repository Abstraction
  - Multiple Storage Repositories
    - Integrity
    - Consistency

- Information Repository Abstraction
  - Metadata servers
    - Collection organization
    - File status, creation
    - Descriptive metadata
    - State Information
Data Management Concepts
(Digital Library)

• Collection
  – The organization of digital entities to simplify management and access.

• Context
  – The information that describes the digital entities in a collection.

• Content
  – The digital entities in a collection
SCEC Digital Library
SCEC Persistent Archive

- **Portals**
  - Knowledge interface to the library, presenting a coherent view of the services

- **Knowledge Management Systems**
  - Organize relationships between SCEC concepts and semantic labels

- **Process management systems**
  - Data processing pipelines to create derived data products

- **Web services**
  - Uniform capabilities provided across SCEC collections

- **Data grid**
  - Management of collections of distributed data

- **Computational grid**
  - Access to distributed compute resources

- **Persistent archive**
  - Management of technology evolution
Metadata Organization
(Domain View versus Run View)

- Provenance
- Simulation Model
- Program
- Computer System
  - Velocity Model
  - Fault Model
  - Domain
  - ...
  - Spatial
  - Temporal
    - Physical
    - Numerical
      - Run
      - Output
        - Domain List
        - Formatting
View All Metadata

Collection: 00003
Parent Collection: /home/mfaerman2.sdsc/SCEC-CME/Simulations/DFM/Output/Velocity
Owner: mfaerman2@sdsc

Metadata describing entity 00003

Field Name | Value | Units | Explanation |
--- | --- | --- | --- |
TimeStep | 3 | | |
DC.description | 4D wave propagation data | | |
DC.subject.scheme | LCC | | |
DC.subject.content | QE521-545 | | |
DC.type.scheme | DCMIType | | |
DC.type.content | Dataset | | |
DC.rights.Lang | en | | |
DC.date.created | Thu Aug 28 09:09:11 PDT 2003 | | |
DC.creator.Name | Geoffrey Ely | | |
DC.creator.Email | gely@ucsd.edu | | |
DC.contributor | Qiao Xin, Marcio Faerman | | |
DC.publisher.Name | Marcio Faerman | | |
DC.publisher.Email | mfaerman@sdsc.edu | | |
ProgramInfo.Name | dfm | | |
ProgramInfo.Description | DFM: Dynamic Fault Model | | |
ProgramInfo.Authors | Geoffrey Ely, Steve Day, Boris Shkoller | | |
ProgramInfo.Affiliation | UCSD, SDSU | | |
ProgramInfo.ProgrammingLanguages | C, Fortran | | |
ProgramInfo.SystemSoftware: MPICH, bash, gawk, gmake, perl
PhysicalInputs.CoordinateSystem: Cartesian XYZ
PhysicalInputs.Volume.MinX: 0
PhysicalInputs.Volume.MaxX: 2.807
PhysicalInputs.Volume.MinY: 0
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NumericalInputs.FreeSurfaceBoundaryCondition: natural
RunID.Description: High resolution DFM foam rubber simulation
RunID.Submitter.Name: Qiao Xin
RunID.Investigator.Name: Geoffrey Ely
RunID.Date.Submitted: Thu Aug 28 09:09:11 PDT 2003
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Technology Evolution

• All components of the “Persistent Archive” will evolve
  – Hardware systems
  – Software systems
  – Protocols
  – Access methods
  – Encoding syntax for digital entities

• Create drivers for each new storage repository protocol
  – Migrate data to each new storage system

• Manage evolution of the encoding syntax
  – Transformative migration
  – Emulation
  – Characterization of structure and semantics - digital ontology
Managing Technology Evolution

Generic operations executed by APIs

Map from preservation processes to storage access operations

Generic operations for accessing storage systems
Data Grid Abstractions

• Logical name space for files
  – Global persistent identifier

• Storage repository virtualization
  – Standard operations supported on storage systems

• Information repository virtualization
  – Standard operations to manage collections in databases

• Access virtualization
  – Standard interface to support alternate APIs

• Latency management mechanisms
  – Aggregation, parallel I/O, replication, caching

• Security interoperability
  – GSSAPI, inter-realm authentication, collection-based authorization
### SDSC Storage Resource Broker & Meta-data Catalog

#### Application

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<th>Unix Shell</th>
<th>Java, NT Browsers</th>
<th>DLL / Python</th>
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<th>OAI WSDL</th>
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#### Consistency Management / Authorization-Authentication

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#### Catalog Abstraction

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#### Storage Abstraction

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<tr>
<td>Databases DB2, Oracle, Postgres</td>
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#### Access APIs

<table>
<thead>
<tr>
<th>Access APIs</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRB Server</td>
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</tbody>
</table>

#### Drivers

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San Diego Supercomputer Center  
National Partnership for Advanced Computational Infrastructure
Are Repeated Media Migrations Feasible?

• Only migrate to new technology when the cost per Gigabyte is a factor of two lower
  – At SDSC, cartridge capacity has increased from 200 Mbytes to 200 Gbytes for same cartridge cost

• Then the media cost is fixed when summed over all migrations
  \[
  (1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} + \frac{1}{32} + \ldots) = 2
  \]

• SDSC migrates to new media to reduce cost
  – Minimize floor space requirements
  – Minimize labor support requirements
  – All tape are stored in robots to minimize labor costs
Transformative Migration versus Emulation versus Digital Ontology

• Transformative Migration
  – Transform the encoding format to a new standard
  – Can combine encoding format transformation with media migration

• Emulation
  – Create a transportable parser for the original encoding format
  – Migrate emulator forward in time
  – Example - Multivalent Browser (written in Java) for parsing pdf, LaTeX, …

• Digital ontology
  – Characterize the structures and relationships present within the digital entity
  – Migrate the characterization forward in time
Managing Technology Evolution (Digital Ontologies)

Generic operations for data display and manipulation

Map from data manipulation operations to data parsing operations

Generic operations for parsing encoding formats and data structures
Managing Technology Evolution (Digital Ontologies)

Operations for data display and manipulation

Operations for parsing encoding formats and data structures
Managing Technology Evolution (Digital Ontologies)

Characterization of application operations

Mechanism for enabling a current application to parse prior encoding formats

Characterization of encoding format
Managing Technology Evolution (Digital Ontologies)

Characterization of application operations

Mechanism for future applications to manipulate current encoding format

Characterization of encoding format
Preservation Architecture
(Data & Metadata Replication)

Preservation Facility

Deep Archive

Fault tolerance
Load balancing
Disaster recovery

Replication Facility

Disaster recovery
No user access
Preservation Name Spaces

• Resources
  – Controls on which zones may use a resource

• User names (user-name / domain / SRB-zone)
  – Users may be registered into another domain, but retain their home zone, similar to Shibboleth

• Data files
  – Controls on who specifies replication of data

• Context metadata
  – Controls on who manages updates to metadata
Preservation Architecture

- Preservation Facility
  - Replicate
    - files
    - metadata
  - System access

- Replicate Facility
  - Replicate
    - files
    - metadata
  - User access

- Deep Archive
  - Disaster recovery
  - No user access

- Fault tolerance
- Load balancing
- Disaster recovery
Deep Archive

• Impose sharing constraints:
  – Only system administrator access
  – Selected replication of files
  – Write once, with versions created on changes to data
• Impose consistency constraints
  – Coordinate update of preservation metadata with file replication
• Manage replication of both data and metadata
• Use federation to guarantee preservation against
  – Local hardware and software failures
  – Local operation errors
  – Local disasters
# Data Grid Federation - zoneSRB

<table>
<thead>
<tr>
<th>C, C++, Java Libraries</th>
<th>Linux I/O</th>
<th>Unix Shell</th>
<th>Java, NT Browsers</th>
<th>DLL / Python, Perl</th>
<th>HTTP</th>
<th>OAI, WSDL, OGSA</th>
</tr>
</thead>
</table>

## Federation Management

### Consistency & Metadata Management / Authorization-Authentication Audit

- **Logical Name Space**
- **Latency Management**
- **Data Transport**
- **Metadata Transport**

## Catalog Abstraction

- **Databases**
  - DB2, Oracle, Sybase, Postgres, mySQL, Informix

## Storage Repository Virtualization

- **Archives - Tape**
  - HPSS, ADSM, UniTree, DMF, CASTOR, ADS
- **ORB**
- **File Systems**
  - Unix, NT, Mac OSX
- **Databases**
  - DB2, Oracle, Sybase, SQLserver, Postgres, mySQL, Informix
For More Information

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http://www.npaci.edu/DICE

http://www.npaci.edu/DICE/SRB

http://www.npaci.edu/dice/srb/mySRB/mySRB.html