SciDB User's Guide

SciDB User's Guide

Version 12.3

Table of Contents

List of Tables

Chapter 1. Introduction to SciDB

SciDB is an all-in-one data management and advanced analytics platform. It provides massively scalable complex analytics inside a next-generation database with data versioning and provenance to support the needs of commercial and scientific applications. SciDB is an open source software platform that runs on a grid of commodity hardware or in a cloud.

Paradigm4 Enterprise SciDB with Paradigm4 Extensions is an enterprise distribution of SciDB with additional linear algebra operations, high availability options, and client connector features.

Unlike conventional relational databases designed around a row or column-oriented table data model, SciDB is an array database. The native array data model provides compact data storage and high performance operations on ordered data such as spatial (location-based) data, temporal (time series) data, and matrix-based data for linear algebra operations.

This document is a User's Guide, written for scientists and developers in various application areas who want to use SciDB as their scalable data management and analytic platform.

This chapter introduces the key technical concepts in SciDB—its array data model, basic system architecture including distributed data management, salient features of the local storage manager, and the system catalog. It also provides an introduction to SciDB's array languages—Array Query Language (AQL) and Array Functional Language (AFL)—and an overview of transactions in SciDB.

1.1. Array Data Model

SciDB uses multidimensional arrays as its basic storage and processing unit. A user creates a SciDB array by specifying *dimensions* and *attributes* of the array.

Dimensions

An n-dimensional SciDB array has dimensions d1, d2, ..., dn. The *size* of the dimension is the number of ordered values in that dimension. For example, a 2-dimensional array may have dimensions *i* and *j*, each with values (1, 2, 3, ..., 10) and (1, 2, ..., 30) respectively.

Basic array dimensions are 64-bit integers. SciDB also supports arrays with one or more noninteger dimensions, such as variable-length strings (*alpha*, *beta*, *gamma*, ...) or floating-point values (1.2, 2.76, 4.3, ...).

When the total number of values or cardinality of a dimension is known in advance, the SciDB array can be declared with a *bounded* dimension. However, in many cases, the cardinality of the dimension may not be known at array creation time. In such cases, the SciDB array can be declared with an *unbounded* dimension.

Attributes

Each combination of dimension values identifies a cell or element of the array, which can hold multiple data values called attributes (a1, a2, ..., am). Each data value is referred to as an *attribute*, and belongs to one of the supported datatypes in SciDB.

At array creation time, the user must specify:

- An array name.

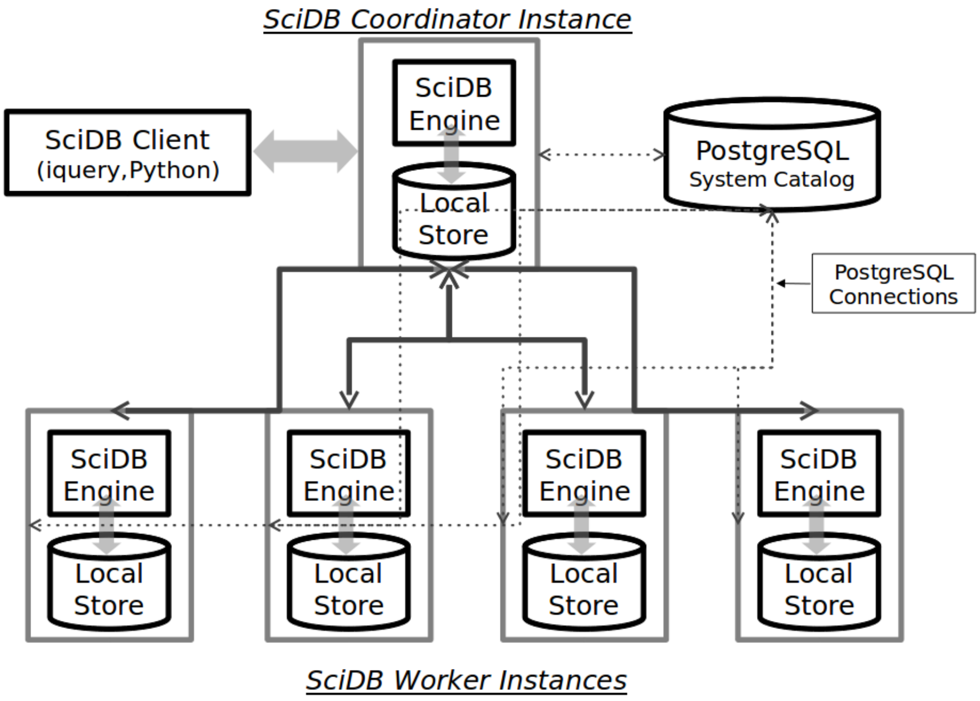
- Array dimensions. The name and size of each dimension must be declared.

- Array attributes of the array. The name and data type of the each attribute must be declared.

Once you have created a SciDB database and defined the arrays, you must prepare and load data into it. Loaded data is then available to be accessed and queried using SciDB's built-in analytics capabilities.

1.2. Basic Architecture

SciDB uses a *shared-nothing* architecture which is shown in the illustration below.



SciDB is deployed on a cluster of servers, each with processing, memory, and local storage, interconnected using a standard ethernet and TCP/IP network. Each physical server hosts a SciDB instance that is responsible for local storage and processing.

External applications, when they connect to a SciDB database, connect to one of the instances in the cluster. While all instances in the SciDB cluster participate in query execution and data storage, one server is the *coordinator* and orchestrates query execution and result fetching. It is the responsibility of the coordinator instance to mediate all communication between the SciDB external client and the entire SciDB database. The rest of the system instances are referred to as worker instances and work on behalf of the coordinator for query processing.

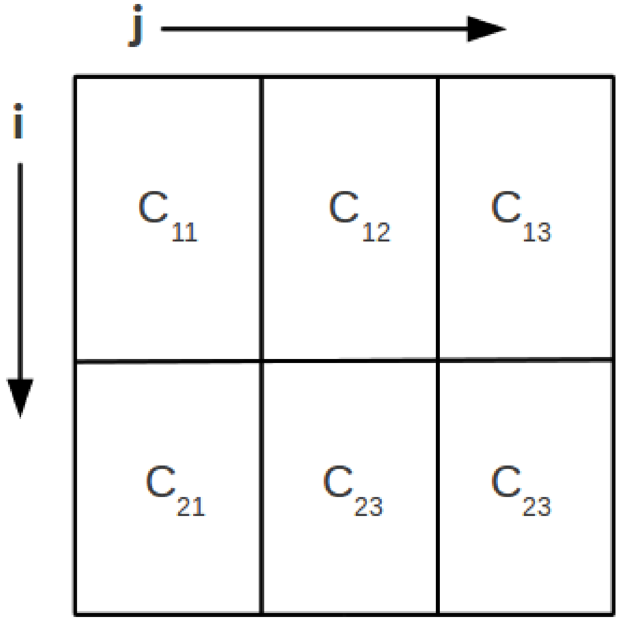
SciDB's scale-out architecture is ideally suited for hardware grids as well as clouds, where additional severs may be added to scale the total capacity.

1.2.1. Chunking and Scalability

When data is loaded, it is partitioned and stored on each instance of the SciDB database. SciDB uses *chunking*, a partitioning technique for multi-dimensional arrays where each instance is responsible for storing and updating a subset of the array locally, and for executing queries that use the locally stored data. By distributing data uniformly across all instances, SciDB is able to deliver scalable performance on computationally or I/O intensive analytic operations on very large data sets.

The details of chunking are shown in this section. Remember that you do not need to manage chunk distribution beyond specifying chunk size.

Chunking is specified for each array as follows. Each dimension of an array is divided into chunks. For example, an array with dimensions `i` and `j`, where `i` is of length 10 and chunk size 5 and `j` is of length 30 and chunk size 10 would be chunked as follows:



Chunks are arranged in row-major order in this example, and stored within the cluster using a round-robin distribution as follows. Suppose a cluster has instances 1 through 4, the placement of data is shown below.

C_{11} -> server 1

C_{12} -> server 2

C_{13} -> server 3

C_{21} -> server 4

C_{22} -> server 1

C_{23} -> server 2

This scheme is generalized to arrays with more dimensions by arranging the chunks in left-to-right dimension order.

1.2.2. Chunk Overlap

It is sometimes advantageous to have neighboring chunks of an array overlap with each other. Overlap is specified for each dimension of an array. For example, consider an array A as follows:

```
A<a: int32>[i=1:10,5,1, j=1:30,10,5]
```

Array A has has two dimensions, `i` and `j`. Dimension `i` is of length 10, chunk size 5, and had chunk overlap 1. Dimension `j` has length 30, chunk size 10, and chunk overlap 5. This overlap causes SciDB to store adjoining cells in each dimension from the *overlap area* in both chunks.

Some advantages of chunk overlap are:

- Speeding up nearest-neighbor queries, where each chunk may need access to a few elements from its neighboring chunks,
- Detecting data clusters or data features that straddle more than one chunk.

SciDB supports operators that can be used to add or change the chunk overlap within an existing array.

1.3. SciDB Array Storage

SciDB arrays consist of array chunk storage and array metadata stored in the system catalog. When arrays are created, updated or removed, they are done using transactions. Transactions span array storage and the system catalog and ensure consistency of the overall database as queries are executed.

The following sections describe SciDB's instance storage, system catalog, and transaction model.

1.3.1. Instance Storage

Vertical partitioning

Each local SciDB instance divides logical chunks of an array into per-attribute chunks, a technique referred to as *vertical partitioning*. All basic array processing steps—storage, query processing, and data transfer between instances—use single-attribute chunks. SciDB uses run-length encoding internally to compress repeated values or commonly occurring patterns typical in scientific applications. Frequently accessed chunks are maintained in an in-memory cache and accelerate query processing by eliminating expensive disk fetches for repeatedly accessed data.

Storage of array versions

SciDB uses a "no overwrite" storage model. No overwrite means that data is never overwritten; each store() or update query writes a new full chunk or a new *delta chunk*. Delta chunks are calculated by differencing the new version with the prior version and only storing the difference. The SciDB storage manager stores "reverse" deltas -- this means that the most recent version is maintained as a full chunk, and prior versions are maintained as a list or chain of reverse deltas. The delta chain is stored in the "reserve" portion of each chunk, an additional area over and above the total size of the chunk. If the reserve area for the chunk fills up, a new chunk is allocated within the same segment or a new segment and linked into the delta chain.

Storage segments

The local storage manager manages space allocation, placement, and reclamation within the local storage manager using *segments*. A storage segment is a contiguous portion of the storage file reserved for successive chunks of the same array. This is designed to optimize queries issued on a very large array to use sequential disk I/O and hence maximize the rate of data transfer during a query.

Segments also serve as the unit of storage reclaim, so that as array chunks are created, written, and ultimately removed, a segment is reclaimed and reallocated for new chunks or arrays once all its member chunks have been removed. This allows for reuse of storage space.

Transient storage	SciDB uses temporary data files or "scratch space" during query execution. This is specified during initialization and start-up as the `tmp-path` configuration setting. Temporary files are managed using the operating system's *tempfile* mechanism. Data written to tempfile only last for the lifetime of a query. They are removed upon successful completion or abort of the query.

1.3.2. SciDB System Catalog

SciDB relies on a system catalog that is a repository of the following information:

- Configuration and status information about the SciDB cluster,
- Array-related metadata such as array definitions, array versions, and associations between arrays and other related objects,
- Information about SciDB extensions, such as plug-in libraries containing user-defined objects, which are described in the section "Array Processing."

The system catalog in current versions of SciDB is implemented as PostgresSQL tables, shared between all SciDB instances within the cluster.

1.3.3. Transactions

SciDB combines traditional ACID semantics with versioned, no overwrite array storage. When using versioned arrays, write transactions create new versions of the array -- they do not modify pre-existing versions of the array.

A scope of a transaction in SciDB is a single statement. Each statement involves many scan, projection, and analytic operators on one or more arrays, and ultimately store the result into a destination array.

SciDB implements array-level locking. Locks are acquired at the beginning of a transaction and are used to protect arrays during queries. Locks are released upon completion of the query. If a query aborts, pending changes are undone at all instances in the system catalog, and the database is returned to a prior consistent state.

1.4. Array Processing

SciDB's query language and operators provide the basic framework for scalable array processing.

1.4.1. Array Language

SciDB provides two query language interfaces.

- AQL, the Array Query Language
- AFL, the Array Functional Language

SciDB's Array Query Language (AQL) is a high-level declarative language for working with SciDB arrays. It is similar to the SQL language for relational databases, but uses an array-based data model and a more comprehensive analytical query set compared with standard relational databases.

AQL represents the full set of data management and analytic capabilities including m data loading, data selection and projection, aggregation, and joins.

The AQL language includes two classes of queries:

- **Data Definition Language** (DDL) : commands to define arrays and load data.
- **Data Manipulation Language** (DML) : commands to access and operate on array data.

AQL statements are handled by the SciDB query compiler which translates and optimizes incoming statements into an execution plan.

SciDB's Array Functional Language (AFL) is a functional language for working with SciDB arrays. AFL *operators* are used to compose queries or statements.

1.4.2. Building Blocks

There are four building blocks that you use to control and access your data. These building blocks are:

Operators
SciDB operators, such as join, take one or more SciDB arrays as input and return a SciDB array as output.

Functions
SciDB functions, such as sqrt, take scalar values from a literals or a SciDB arrays and return a scalar value.

Data types
Data types define the classes of values that SciDB can store and perform operations on.

Aggregates
SciDB aggregates take an arbitrarily large set of values as input and return a scalar value.

Any of these building blocks can be user-defined. See the chapter on SciDB Plugins for how to create a user-defined datatype (UDT), user-defined operator (UDO), user-defined function (UDF), or user-defined aggregate (UDA).

1.4.3. Pipelined Array Processing

SciDB's query language and operators provide the basic framework for scalable array processing.

When a SciDB query is issued, it is setup as a pipeline of operators. Operators are responsible for data processing, aggregation as well as intermediate data exchange, and data storage.

Execution begins when the client issues a fetch chunk request for the result array. Data is then scanned from array storage on all instances and streamed into and out of each operator one chunk at a time. This model of query execution is sometimes referred to as "pull based" execution. Some operators implement algorithms that require the entire array to be materialized in memory at all instances at once, these are referred to as materializing operators. Unless required by the data processing algorithm, all SciDB operators are streaming operators.

1.5. Clients and Connectors

The SciDB software package that you downloaded contains a special command line utility called *iquery* which provides an interactive Linux shell and supports both AQL and AFL. For more information about iquery, see Getting Started With SciDB Development.

Client applications connect to SciDB using an appropriate connector package which implements the client-side of the SciDB client-server protocol. Once connected via the connector, the user may issue queries written in either AFL or AQL, and fetch the result of a query using an iterator interface.

1.6. Conventions Used in this Document

Code to be typed in verbatim is shown in `fixed-width font`. Code that is to be replaced with an actual string is shown in *italics*. Optional arguments are shown in square brackets [].

Chapter 2. SciDB Installation and Administration

2.1. Installing SciDB

SciDB binaries are currently available for the following Linux platforms:

- Red Hat Enterprise Linux 5.4
- Fedora 11
- Ubuntu 11.04

For virtual machine–based installs, you can use VMWare Player or VBox for desktop testing and Citrix XenServer for production use.

The following terms are used to describe the SciDB installation and administration process:

Instance

An independent SciDB process, that is, a single runnable copy of SciDB. There may be a many-to-one mapping between SciDB instances and a single server.

Cluster

A group of one or more single servers connected by TCP/IP, working together as a single system, and sharing data. A cluster can be a private grid or a public cloud.

Single server

A configuration that consists of a single machine with a processor that may contain any number of cores, memory and attached storage. A single server may be virtual or physical. A single server is not connected to nor does it share data with any other servers in a cluster.

Virtual server

A server that shares hardware rather than having dedicated hardware.

2.1.1. Preparing the Platform

2.1.1.1. Linux User Account

First, you will need to create a Linux user account, **scidb**. This account will be used to run all SciDB processes and own all files created by SciDB. The **scidb** user account must have superuser privileges. It is also helpful to set up the account for access to the system without password entry.

To create the account, modify the `/etc/sudoers` file as follows:

```
## Allow root to run any commands anywhere
root    ALL=(ALL)       ALL
scidb   ALL=(ALL)       NOPASSWD: ALL
```

2.1.1.2. Postgres Installation and Configuration

SciDB has been tested with Postgres 8.4.X. A suitable version of Postgres (8.4.6 or 8.4.7) is typically available on most Linux platforms.

On Ubuntu, you can use apt-get to install the postgresql-contrib package:

```
sudo apt-get install postgresql-contrib
```

On Red Hat and Fedora, you can use `yum` :

```
sudo yum install postgresql-contrib
```

By default, Postgres is configured to allow only local access via Unix-domain sockets. In a cluster environment, the Postgres database needs to be configured to allow access from other instances in the cluster. To do this:

1. Modify the `pg_hba.conf` file (usually at `/etc/postgresql/8.4/main/` or `/var/lib/pgsql/data/`) by adding the following line:

   ```
   host    all      all     10.0.0.1/8       trust
   ```

2. In the `pg_hba.conf` file, change all instances of 'ident' to 'trust' (assuming your local network is 10.x.x.x).

3. Restart Postgres.

Warning

This Postgres configuration might pose security issues. When authentication is set to trust PostgreSQL assumes that anyone who can connect to the server is authorized to access the database. To make a more secure installation, you can list specific host IP addresses, user names, and role mappings.

You can read more on the security details of Postgres client-authentication in the Postgres documentation at http://www.postgresql.org/docs/8.3/static/client-authentication.html.

You might need to set the `postgresql.conf` file to have it listen on the relevant port and IP address, as it might be limited to `localhost` by default.

If you are running a cluster with multiple servers, you will also need to modify the `postgresql.conf` file to allow connections:

```
# - Connection Settings -
listen_addresses = '*'
```

You can verify that a PostgreSQL instance is running on the coordinator with the `status` command:

```
sudo /etc/init.d/postgresql-8.4 status
sudo /etc/init.d/postgresql-8.4 start
```

Note

- Red Hat Enterprise Linux 5.4 comes with PostgreSQL 8.1. We recommend upgrading to version 8.4.7.

- Add Postgres startup scripts to the Linux initialization scripts to start Postgres automatically after a reboot.
- If your **scidb** user does *not* have *sudo* privileges, have your administrator use the following procedure to initialize Postgres:

  1. Create a new role or account (say *test1user*) with password (say *test1passwd*).
  2. Create a database for testing scidb (say *test1*) using the new account.
  3. Create a schema in that newly created Postgres database to hold the SciDB catalog data:

     ```
     root$ sudo -u postgres
            /opt/scidb/12.3/bin/scidb-prepare-db.sh
     ```

The last step, after you have configured Postgres, is to add it to Linux system services. This means that Postgres will be started automatically on system reboot:

```
sudo /sbin/chkconfig --add postgresql
```

2.1.1.3. Remote Execution Configuration (ssh)

SciDB uses ssh for remote execution of cluster management commands. This is why the **scidb** user account should have no-password ssh access from the coordinator to the workers and from the coordinator to itself.

The python-crypto (64-bit) and python-paramiko packages are required for SciDB on Red Hat 5.4. These packages are ssh packages in python. You can install the python ssh client packages as follows:

```
sudo apt-get install python, python-crypto, python-paramiko
```

There are several methods to configure password-less ssh between servers. We recommend the following simple method.

1. Create a key:

   ```
   ssh-keygen
   ```

2. Copy the key to the localhost (or coordinator) and to each worker:

   ```
   ssh-copy-id scidb@worker
   ssh-copy-id scidb@localhost
   ```

3. Login to remote host. Note that no password is required now:

   ```
   ssh scidb@worker
   ```

2.1.1.4. Shared file system

To run SciDB in a cluster , export the `/opt/scidb` directory on the coordinator using NFS or samba. To do this, configure the export and restart the NFS service like this:

```
# Configure the export
/opt/scidb *(ro,no_root_squash,sync)

# Restart the nfs service
sudo /etc/init.d/nfs restart
```

Mount this on all workers using the same directory path (`/opt/scidb`) as the mount point. Add this line to the `/etc/fstab` file to mount the shared file system on each worker:

```
# SciDB coordinator mount point
10.0.0.1:/opt   /opt   nfs    ro,rsize=8192,wsize=8192,timeo=14,intr
```

The coordinators and workers access binaries, shared libraries, plugins, configuration files from `/opt/scidb`.

The last step, after you have configured NFS, is to add it to Linux system services. This means that NFS will be started automatically on system reboot:

```
sudo /sbin/chkconfig --add nfs
```

2.1.2. Install SciDB from binary package

If you are installing a downloaded pre-built binary package, you can install it using `dpkg` for Ubuntu and `rpm` or `yum` for Red Hat. We currently provide packages for Ubuntu and RPMs for Red Hat and Fedora.

2.1.2.1. Ubuntu

Install

1. Install the libscidbclient package:

   ```
   sudo dpkg  -i libscidbclient.*.deb
   ```

   You may want to install the optional debug symbols package:

   ```
   sudo dpkg -i libscidbclient.*.deb
   ```

2. Install the SciDB package:

   ```
   sudo dpkg -i scidb.*.deb
   ```

   You may want to install the optional debug symbols package:

   ```
   sudo dpkg -i scidb-dbg.*.deb
   ```

Note

`dpkg` does not resolve dependencies and you may need to manually install the dependencies or use apt-get to resolve any unmet dependencies on the system. This could happen on either the libscidbclient or SciDB package install. For example:

```
# Fails due to unmet dependencies
sudo dpkg -i scidb.*.deb

# Installs dependencies
sudo apt-get -f install

# Succeeds now
sudo dpkg -i scidb-RelWithDebInfo-12.3.*.deb
```

Uninstall

Uninstall SciDB as follows:

```
sudo dpkg -r scidb-dbg
sudo dpkg -r scidb
sudo dpkg -r libscidbclient-dbg
sudo dpkg -r libscidbclient
```

2.1.2.2. Red Hat and Fedora

Install:

1. Install the libscidbclient package:

   ```
   sudo rpm --force -ivh libscidbclient-RelWithDebInfo-12.3.*.rpm
   ```

   You may want to install the optional debug symbols package:

   ```

   sudo rpm --force -ivh
   libscidbclient-dbg.*.rpm
   ```

2. Next, install the SciDB server package:

   ```
   sudo rpm --force -ivh scidb-12.3.*.rpm
   ```

   You may want to install the optional debug symbols package:

   ```
   sudo rpm --force -ivh scidb-dbg.*.rpm
   ```

Uninstall:

To uninstall SciDB, do the following:

```
sudo rpm -e scidb-dbg
sudo rpm -e scidb
sudo rpm -e libscidbclient-dbg
sudo rpm -e libscidbclient
```

2.1.2.3. Environment Variables

Now you need to configure the environment of the **scidb** user account. The following lines should be added to the user's shell configuration file (often `.profile` or `.bashrc`):

```
export SCIDB_VER=12.3
export PATH=/opt/scidb/$SCIDB_VER/bin:/opt/scidb/$SCIDB_VER/share/scidb:$PATH
export LD_LIBRARY_PATH=/opt/scidb/$SCIDB_VER/lib:$LD_LIBRARY_PATH
```

2.2. Configuring SciDB

This chapter demonstrates how to configure SciDB prior to initialization, including checking that the PostgreSQL DBMS is running, that the SciDB configuration file (usually `/opt/scidb/12.3/etc/config.ini`) is set up, and that logging is configured.

2.2.1. SciDB Configuration File

You need to create a configuration file for SciDB. By default, it is named `config.ini` and it resides in the `etc` sub-directory of the installation tree. (By default it is `/opt/scidb/12.3/etc/config.ini`.) The configuration file can have multiple sections, one per service instance.

The configuration 'test1' below is an example of the configuration for a single-instance system (coordinator only):

```
[test1]
instance-0=localhost,0
db_user=test1user
db_passwd=test1passwd
install_root=/opt/scidb/12.3
metadata=/opt/scidb/12.3/share/scidb/meta.sql
pluginsdir=/opt/scidb/12.3/lib/scidb/plugins
logconf=/opt/scidb/12.3/share/scidb/log4cxx.properties
base-path=/home/scidb/data
base-port=1239
interface=eth0
no-watchdog=true
redundancy=1
merge-sort-buffer=1024
network-buffer=1024
mem-array-threshold=1024
smgr-cache-size=1024
execution-threads=16
result-prefetch-queue-size=4
result-prefetch-threads=4
chunk-segment-size=10485760
```

2.2.2. Cluster Configuration Example

The following SciDB cluster configuration is called 'monolith'. This cluster consists of eight identical virtual servers:

- x86 6-core processor
- 8 GB of RAM
- 1 TB direct attached storage
- 1Gbps Ethernet
- RHEL 5.4

The following configuration file applies to such a cluster and is explained in the following section.

```
[monolith]
# server-id=IP, number of worker instances
server-0=10.0.20.231,0
server-1=10.0.20.232,1
server-2=10.0.20.233,1
server-3=10.0.20.234,1
server-4=10.0.20.235,1
server-5=10.0.20.236,1
```

```
server-6=10.0.20.237,1
server-7=10.0.20.238,1
db_user=monolith
db_password=monolith
install_root=/opt/scidb/12.3
metadata=/opt/scidb/12.3/share/scidb/meta.sql
pluginsdir=/opt/scidb/12.3/lib/scidb/plugins
logconf=/opt/scidb/log4cxx.properties.trace
base-path=/data/monolith_data
base-port=1239
interface=eth0
```

The install package contains a sample configuration file, `sample_config.ini`, with examples.

The following table describes the basic configuration file settings:

Basic Configuration	
Key	**Value**
Cluster name	Name of the SciDB cluster. The cluster name must appear as a section heading in the config.ini file, e.g., *[cluster1]*
server-N	The host name or IP address used by server N and the number of worker instances on it. Server 0 always has the coordinator running as instance 0, and may have additional worker instances running as well.
db_user	Username to use in the catalog connection string. This example uses *test1user*
db_passwd	Password to use in the catalog connection string. This example uses *test1passwd*
install_root	Path name of install root.
metadata	Metadata definition file.
pluginsdir	The folder or directory in which plugins are stored.
logconf	**log4xx** configuration file.

The following table describes the cluster configuration file contents and how to set them:

Cluster Configuration	
Key	**Value**
base-path	The root data directory for each SciDB instance. Each SciDB instance initializes its data directory within the base-path. Path `scidb/00`*`n`*`/1` will be the path for instance *`n`*.
base-port	Base port number. Connections to the coordinator (and therefore to the system) are via this number, while worker instances communicate at base-port + instance number. The default number that `iquery` expects is 1239.
interface	Ethernet interface that SciDB must use.
ssh-port (optional)	The port that ssh uses for communications within the cluster. Default:22.
key-file-list (optional)	Comma-separated list of filenames that include keys for ssh authentication. Default: None.
tmp-path (optional)	The directory to use as temporary space.
no-watchdog (optional)	Set this to true if you do not want automatic restart of the SciDB server on a software crash. Default: false.

The following table describes the configuration file elements for tuning your system performance:

Performance Configuration	
Key	**Value**
save-ram (optional)	'True', 'true', 'on' or 'On' will enable this option. Off by default. This allows you to store temporary data in memory. It is not advisable to do this; it is better to store temporary data in files.
merge-sort-buffer (optional)	Size of memory buffer used in merge sort. Default: 512 MB.
mem-array-threshold (optional)	Maximum memory used for temporary arrays. Default: 1024 MB.
chunk-reserve (optional)	Percentage of chunk preallocated to store chunk deltas. Setting this parameter to 0 disables the delta mechanism. Default: 10%.
chunk-segment-size (optional)	Size in bytes of a storage segment. A storage segment is a unit of allocation and reclamation used by storage manager. If set to zero, no space reuse or storage reclamation is done.
execution-threads (optional)	Size of thread pool available for query execution. Shared pool of threads used by all queries for network IO and some query execution tasks. Default: 4.
result-prefetch-threads (optional)	Per-query threads available for prefetch. Default: 4.
result-prefetch-queue-size (optional)	Per-query number of result chunks to prefetch. Default: 4.
smgr-cache-size (optional)	Size of buffer cache. Default: 256 MB

In the example above, `db_user` is set to *test1user* and `db_passwd` is set to *test1passwd*.

2.2.3. Logging Configuration

SciDB uses Apache's log4cxx (http://logging.apache.org/log4cxx/) for logging.

The logging configuration file, specified by the `logconf` variable in `config.ini`, contains the following Apache log4cxx logger settings:

```
###
# Levels: TRACE < DEBUG < INFO < WARN < ERROR < FATAL
###

log4j.rootLogger=DEBUG, file

log4j.appender.file=org.apache.log4j.RollingFileAppender
log4j.appender.file.File=scidb.log
log4j.appender.file.MaxFileSize=10000KB
log4j.appender.file.MaxBackupIndex=2
log4j.appender.file.layout=org.apache.log4j.PatternLayout
log4j.appender.file.layout.ConversionPattern=%d [%t] [%-5p]: %m%n
```

2.3. Initializing and Starting SciDB

2.3.1. The scidb.py Script

To begin a SciDB session, use the `scidb.py` script. In a standard SciDB build, this script is located at:

```
/opt/scidb/version.number/bin
```

The syntax for the `scidb.py` script is:

```
scidb.py command db conffile
```

The options for the *`command`* argument are:

`initall`	Initialize the system catalog. **Warning**: This will remove any existing SciDB arrays from the current namespace.
`startall`	Start a SciDB instance.
`stopall`	Stop the current SciDB instance.
`status`	Show the status of the current SciDB instance.
`dbginfo`	Collect debugging information by getting all logs, cores, and install files.
`dbginfo-lt`	Collect only stack and log information for debugging.
`version`	Show SciDB version number.

The *`db`* argument is the name of the SciDB cluster you want to create or get information about.

The configuration file is set by default to `/opt/scidb/12.3/etc/config.ini`. If you want to use a custom configuration file for a particular SciDB cluster, use the *`conffile`* argument.

Run the following command to initialize SciDB on the server. If the SciDB user has sudo privileges, everything will be done automatically (otherwise see the previous section for additional Postgres configuration steps):

```
scidb.py initall test1
```

Warning

This will reinitialize the SciDB database. Any arrays that you have created in previous SciDB sessions will be removed and the memory reclaimed.

To start the set of local SciDB instances specified in your config.ini file, use the following command:

```
scidb.py startall test1
```

This will report the status of the various instances:

```
scidb.py status test1
```

This will stop all SciDB instances:

```
scidb.py stopall test1
```

SciDB logs are written to the file `scidb.log` in the appropriate directories for each instance: <base-path>/000/0 for the coordinator and <base-path>/M/N the worker M instance N.

2.4. Upgrading SciDB

The name `test1` in the following examples refers to the SciDB database. All of the following steps are performed as Linux user **scidb**.

- Shutdown SciDB:

  ```
  scidb.py stopall test1
  ```

- Download and install the latest SciDB package using the standard package manager on your platform (rpm or dpkg).

  If you are installing a downloaded pre-built binary package, you can install it using `dpkg` for Ubuntu and `rpm` or `yum` for Red Hat. We currently provide packages for Ubuntu and RPMs for Red Hat and Fedora.

2.4.1. Ubuntu

1. First, upgrade the libscidbclient package :

   ```
   sudo dpkg -i libscidbclient.*.deb
   ```

   You may want to install the optional debug symbols:

   ```
   sudo dpkg -i libscidbclient-dbg.*.deb
   ```

2. Then install the SciDB package:

   ```
   sudo dpkg -i scidb-RelWithDebInfo-12.3.deb
   ```

   You may want to install the optional debug symbols:

   ```
   sudo dpkg -i scidb-dbg-RelWithDebInfo-12.3.deb
   ```

2.4.2. Red Hat and Fedora

1. First, you need to install the libscidbclient package:

   ```
   sudo rpm --force -Uvh libscidbclient-RelWithDebInfo-12.3.*.rpm
   ```

   If you prefer, you can install with debug symbols:

   ```
   sudo rpm --force -Uvh libscidbclient-dbg-RelWithDebInfo-12.3.*.rpm
   ```

2. Next, install the SciDB server package:

   ```
   sudo rpm --force -Uvh scidb-12.3.*.rpm
   ```

   If you prefer, you can install debug symbols:

   ```
   sudo rpm --force -Uvh scidb-dbg-.*.rpm
   ```

3. Copy over the previous `config.ini` from your earlier version:

   ```
   cp /opt/scidb/12.3/etc/config.ini /opt/scidb/11.12/etc/config.ini
   ```

2.4.3. Additional Steps

- Modify the config.ini file that you just copied. Change all references to your previous version to the new version (ex: `install_root=/opt/scidb/12.3`)

- Edit your environment and update PATH and LD_LIBRARY_PATH:

```
export SCIDB_VER=12.3
export PATH=/opt/scidb/$SCIDB_VER/bin:/opt/scidb/$SCIDB_VER/share/scidb:$PA\
TH
export LD_LIBRARY_PATH=/opt/scidb/$SCIDB_VER/lib:$LD_LIBRARY_PATH
```

- **NOTE:** SciDB 12.3 does not accept storage files from earlier versions. You must reinitialize and reload data:

```
which scidb.py # Make sure you are running 12.3
scidb.py initall test1
scidb.py startall test1
scidb.py status test
```

Chapter 3. Getting Started with SciDB Development

3.1. Using the iquery Client

The `iquery` executable is the basic command-line tool for communicating with SciDB. `iquery` is the default SciDB client used to issue AQL and AFL commands. Start the `iquery` client by typing `iquery` at the command line when a SciDB session is active:

```
scidb.py startall scidb_server
iquery
```

By default, `iquery` opens an AQL command prompt:

```
AQL%
```

You can then enter AQL queries at the command prompt. To switch to AFL queries, use the set command:

```
AQL% set lang afl;
```

AQL statements end with a semicolon (;).

To see the internal `iquery` commands reference type `help` at the prompt:

```
AQL% help;
set             - List current options
set lang afl    - Set AFL as querying language
set lang aql    - Set AQL as querying language
set fetch       - Start retrieving query results
set no fetch    - Stop retrieving query results
set timer       - Start reporting query setup time
set no timer    - Stop reporting query setup time
set verbose     - Start reporting details from engine
set no verbose  - Stop reporting details from engine
quit or exit    - End iquery session
```

You can pass an AQL query directly to `iquery` from the command line using the -q flag:

```
iquery -q "my AQL statement"
```

You can also pass a file containing an AQL query to `iquery` with the -f flag:

```
iquery -f my_input_filename
```

AQL is the default language for `iquery`. To switch to AFL, use the -a flag:

```
iquery -aq "my AFL statement"
```

Each invocation of `iquery` connects to the SciDB coordinator instance, passes in a query, and prints out the coordinator instance's response. `iquery` connects by default to SciDB on port 1239. If you use a port number that is not the default, specify it using the "-p" option with `iquery`. For example, to use port 9999 to run an AFL query contained in the file `my_filename`:

```
iquery -af my_input_filename -p 9999
```

The query result will be printed to stdout. Use -r flag to redirect the output to a file:

```
iquery -r my_output_filename -af my_input_filename
```

To change the output format, use the -o flag:

```
iquery -o csv -r my_output_filename.csv -af my_input_filename
```

Available options for output format are csv, csv+, lcsv+, sparse, and lsparse. These options are described in the following table:

Output Option	**Description**
auto (default)	SciDB array format
csv	Comma-separated values
csv+	Comma-separated values with dimension indices
lcsv+	Comma-separated values with dimension indices and a boolean flag attribute EmptyTag showing if a cell is empty
sparse	Sparse SciDB array format
lsparse	Sparse SciDB array format and a boolean flag attribute EmptyTag showing if a cell is empty

To see a list of the `iquery` switches and their descriptions, type `iquery -h` or `iquery --help` at the command line. The switches are explained in the following table:

iquery Switch Option	**Description**
`-c [ --host ]` *host_name*	Host of one of the cluster instances. Default is 'localhost'.
`-p [ --port ]` *port_number*	Port for connection. Default is 1239.
`-q [ --query ]` *query*	Query to be executed.
`-f [ --query-file ]` *input_filename*	File with query to be executed.
`-r [ --result ]` *target_filename*	Filename with result array data.
`-o [ --format ]` *format*	Output format: auto, csv, csv+, lcsv+, sparse, lsparse. Default is 'auto'.
`-v [ --verbose ]`	Print the debugging information. Disabled by default.
`-t [ --timer ]`	Query setup time (in seconds).
`-n [ --no-fetch ]`	Skip data fetching. Disabled by default.
`-a [ --afl ]`	Switch to AFL query language mode. Default is AQL.
-u `[ --plugins ]`*path*	Path to the plugins directory.
`-h [ --help ]`	Show help.
`-V [ --version ]`	Show version information.
`ignore-errors`	Ignore execution errors in batch mode.

The `iquery` interface is case sensitive.

3.2. iquery Configuration

You can use a configuration file to save and restore your `iquery` configuration. The file is stored in `~/.config/scidb/iquery.conf`. Once you have created this file it will load automatically the next time you start `iquery`. The allowed options are:

host	Host name for the cluster instance. Default is `localhost`.
port	Port for connection. Default is 1239.
afl	Start AFL command line
timer	Report query run-time (in seconds).
verbose	Print debug information.
format	Set the format of query output. Options are csv, csv+, lcsv+, sparse, and lsparse.
plugins	Path to the plugins directory

For example, your `iquery.conf` file might look like this:

```
{
"host":"myhostname",
"port":9999,
"afl":true,
"timer":false,
"verbose":false,
"format":"csv+",
"plugins":"./plugins"
}
```

The opening and closing braces at the beginning and end of the file must be present and each entry (except the last one) should be followed by a comma.

3.3. Example iquery session

This section demonstrates how to use iquery to perform simple array tasks like:

- Create a SciDB array
- Prepare an ASCII file in the SciDB *dense* load file format
- Load data from that file into the array.
- Execute basic queries on the array.
- Join two arrays containing related data.

The following example creates an array, generates random numbers and stores them in the array, and saves the array data into a csv-formatted file.

1. Create an array called random_numbers with:
    - 2 dimensions, x = 9 and y = 10
    - One double attribute called `num`
    - Random numerical values in each cell

```
iquery -aq "store(build(<num:double>[x=0:8,1,0, y=0:9,1,0],
random()),random_numbers)"
```

2. Save the values in random_numbers in csv format to a file called `/tmp/random_values.csv`:

```
iquery -o csv -r /tmp/random_values.csv -aq "scan(random_numbers)
```

The following example creates an array, loads existing csv data into the array, performs simple conversions on the data, joins two arrays with related data set, and eliminates redundant data from the result.

1. Create an array, `target`, in which you are going to place the values from the csv file:

```
iquery -aq "create array target <name:string,mpg:double>[x=0:*,1,0]"
```

2. Starting from a csv file, prepare a file to load into a SciDB array. Use the file *datafile.csv:*

```
Model,MPG
CRV, 23.5
Prius, 48.7
Explorer, 19.6
Q5, 26.8
```

3. Convert the file to SciDB format with the command csv2scidb:

```
csv2scidb -p SN -s 1 < /tmp/datafile.csv > /tmp/datafile.scidb
```

   Note: `csv2scidb` is a separate data preparation utility provided with SciDB. To see all options available for csv2scidb, type `csv2scidb --help` at the command line.

4. Use the load command to load the SciDB-formatted file you just created into `target`:

```
iquery -aq "load(target, '/tmp/datafile.scidb')"
[("CRV",23.5),("Prius",48.7),
("Explorer",19.6),("Q5",26.8)]
```

5. By default, iquery always re-reads or retrieves the data that has just written to the array. To suppress the print to screen when you use the load command, use the -n flag in iquery:

```
iquery -naq "load(target, '/tmp/datafile.scidb')"
```

6. Now, suppose you want to convert miles-per-gallon to kilometers per liter. Use the apply function to perform a calculation on the attribute values `mpg`:

```
iquery -aq "apply(target,kpl,mpg*.4251)"
```

```
 [("CRV",23.5,9.98985),("Prius",48.7,20.7024),
 ("Explorer",19.6,8.33196),("Q5",26.8,11.3927)]
```

   Note that this does not update `target`. Instead, SciDB creates an result array with the new calculated attribute `kpl`. To create an array containing the kpl attribute, use the `store` command:

```
iquery -aq "store(apply(target,kpl,mpg*.4251),target_new)"
```

7. Suppose you have a related data file, datafile_price.csv:

```
Make,Model,Price
Honda,CRV,26700
```

```
Toyota,Prius,31000
Ford, Explorer,42000
Audi,Q5,45000
```

You want to add the data on price and make to your array. Use csv2scidb to convert the file to SciDB data format:

```
csv2scidb -p SSN -s 1 < /tmp/datafile_price.csv >
/tmp/datafile_price.scidb
```

Create an array called storage:

```
iquery -aq "create array storage
<make:string, model:string, price:int64>
[x=0:*,1,0]"
```

Load the datafile_price.scidb file into storage:

```
iquery -naq "load(storage, '/tmp/datafile_price.scidb')"
```

8. Now, you want to combine the data in these two files so that each entry has a make, and model, a price, an mpg, and a kpl. You can join the arrays, with the `join` operator:

```
iquery -aq "join(storage,target_new)"
[("Honda","CRV",26700,"CRV",23.5,9.98985),
("Toyota","Prius",31000,"Prius",48.7,20.7024),
("Ford"," Explorer",42000,"Explorer",19.6,8.33196),
("Audi","Q5",45000,"Q5",26.8,11.3927)]
```

Note that attributes 2 and 4 are identical. Before you store the combined data in an array, you want to get rid of duplicated data.

9. You can use the project operator to specify attributes in a specific order:

```
iquery -aq project(target_new,mpg,kpl)
[(23.5,9.98985),(48.7,20.7024),(19.6,8.33196),(26.8,11.3927)]
```

Attributes that are not specified are not included in the output.

10. Use the `join` and `project` operators to put the car data together. For easier reading, use csv as the query output format:

```
iquery -o csv -aq "join(storage,project(target_new,mpg,kpl))"
make,model,price,mpg,kpl
"Honda","CRV",26700,23.5,9.98985
"Toyota","Prius",31000,48.7,20.7024
"Ford"," Explorer",42000,19.6,8.33196
"Audi","Q5",45000,26.8,11.3927
```

Chapter 4. Creating and Removing SciDB Arrays

SciDB organizes data as a collection of multidimensional arrays. Just as the relational table is the basis of relational algebra and SQL, the multidimensional array is the basis for SciDB.

A SciDB database is organized into arrays that have:

- A *name*. Each array in a SciDB database has an identifier that distinguishes it from all other arrays in the same database.
- A *schema*, which is the array structure. The schema contains array *attributes* and *dimensions*.
  1. Each *attribute* contains data being stored in the array's cells. A cell can contain multiple attributes.
  2. Each *dimension* consists of a list of index values. At the most basic level the dimension of an array is represented using 64-bit unsigned integers. The number of index values in a dimension is referred to as the dimension's *size*.

4.1. Create an Array

The AQL `CREATE ARRAY` statement creates a new array and specifies the array schema. The syntax of the `CREATE ARRAY` statement for a bounded array is:

```
CREATE ARRAY array_name
<attributes>
[dimensions]
```

The arguments for the CREATE ARRAY statements are as follows:

`array_name`

The array name that uniquely identifies the array in the database. The maximum length of an array name is 1024 bytes. Array names may not contain the characters `@` or `:` as these characters are reserved for special array types generated by other SciDB operators.

`attributes`

The array attributes contain the actual data. You specify an attribute with:

- *Attribute name*: Name of an attribute. The maximum length of an attribute name is 1024 bytes. No two attributes in the same array can share a name.
- *Attribute type*: Type identifier. One of the data types supported by SciDB. Use the `list('types')` command to see the list of available data types.
- NULL (optional): If unspecified, all attributes are not null, i.e. they must have a value. Optionally, users can specify 'NULL' to indicate attributes that are allowed to contain null values.
- DEFAULT (optional): Specify the value to use when an attribute is NULL or absent.

`dimensions`

Dimensions form the coordinate system for the array. The number of dimensions in an array is the number of coordinates or *indices* needed to specify an array cell. You specify dimensions with:

- *Dimension name*: Each dimension has a name. Just like attributes, each dimension must be named, and dimension names cannot be repeated in the same array. The maximum length of a dimension name is 1024 bytes.
- *Dimension start*: The starting coordinate of a dimension. The default data type is 64-bit integer.
- *Dimension end* or *: The ending coordinate of a dimension, or * if unbounded. The default data type is 64-bit integer for bounded dimensions.
- *Dimension chunk size*: Number of elements per chunk.
- *Dimension chunk overlap*: Number of overlapping cells from a neighboring chunk.

The AQL `CREATE ARRAY` statement creates an array with specified name and schema.

```
AQL% CREATE ARRAY A <x: double, err: double> [i=0:99,10,0, j=0:99,10,0];
```

This statement creates an array with:

- Array name `A`
- An array schema with:
  1. Two attributes: one with name `x` and type `double` and one with name `err` and type `double`
  2. Two dimensions: one with name `i`, starting coordinate 0, ending coordinate 99, chunk size 10, and chunk overlap 0; one with name `j`, starting coordinate 0, ending coordinate 99, chunk size 10, and chunk overlap 0.

To delete an array with AQL, use the `DROP ARRAY` statement:

```
DROP ARRAY A;
```

To create an array with AFL, use the `create_array` operator:

```
AFL% create_array(A,<val:double,err:double>[i=0:99,10,0,j=0:99,10,0]);
```

To remove an array with AFL, use the `remove` operator:

```
AFL% remove(A);
```

4.2. Array Attributes

A SciDB array must have at least one attribute. The attributes of the array are used to store individual data values in array cells.

For example, you may want to create a product database. A 1-dimensional array can represent a simple product database where each cell has a string attribute called `name`, a numerical attribute called `price`, and a datetime attribute called `sold`:

```
CREATE ARRAY products
<name:string, price:float, sold:datetime>
[i=0:*,10,0];
```

Attributes are by default set to not null. To allow an attribute to have value NULL, add NULL to the attribute data type declaration:

```
CREATE ARRAY product_null <name:string NULL,
price:float NULL,
sold:datetime NULL>[i=0:*,10,0];
```

This allows the attribute to store NULL values at data load.

An attribute takes on a default value of 0 when no other value is provided. To set a default value other than 0, set the DEFAULT value of the attribute. For example, this code will set the default value of `price` to 100 if no value is provided:

```
CREATE ARRAY product_dflt
<name:string, price:float default 100.0, sold:datetime>
[i=0:*,10,0];
```

4.3. Array Dimensions

A SciDB array must have at least one dimension. Dimensions form the coordinate system for a SciDB array.

Note

The dimension size is determined by the range from the dimension start to end, so 0:99 and 1:100 would create the same dimension size.

4.3.1. Chunk Overlap

It is sometimes advantageous to have neighboring chunks of an array overlap with each other. Overlap is specified for each dimension of an array. For example, consider an array A with the following schema:

```
A<a: int32>[i=1:10,5,1, j=1:30,10,5]
```

Array A has has two dimensions, `i` and `j`. Dimension `i` has size 10, chunk size 5, and chunk overlap 1. Dimension `j` has size 30, chunk size 10, and chunk overlap 5. SciDB stores cells from the chunk overlap area in both of the neighboring chunks.

Some advantages of chunk overlap are:

- Speeding up nearest-neighbor queries, where each chunk may need access to a few elements from its neighboring chunks,
- Detecting data clusters or data features that straddle more than one chunk.

4.3.2. Unbounded Dimensions

An array dimension can be created as an unbounded dimension by declaring the high boundary as '*'. When the high boundary is set as * the array boundaries are dynamically updated as new data is added to the array. This is useful when the dimension size is not known at CREATE ARRAY time. For example, this statement creates an array named `open` with two dimensions:

- Bounded dimension `I` of size 10, chunk size 10, and chunk overlap 0

- Unbounded dimension `J` of size *, chunk size 10, and chunk overlap 0.

```
CREATE ARRAY open <val:double>[I=0:9,10,0,J=0:*,10,0];
```

4.3.3. Noninteger Dimensions and Mapping Arrays

Basic arrays in SciDB use the int64 data type for dimensions. SciDB also supports arrays with noninteger dimensions. These arrays map dimension *values* of a declared type to an internal int64-array *position*. Mapping is done through special mapping arrays internal to SciDB. Such arrays are useful when you are transforming data into multidimensional format where some dimensions represent factors or categories.

For example, the array D has a noninteger dimension named ID:

```
AQL% SELECT * FROM show(D);
```

```
[("D <val:int64 ,empty_indicator:indicator >
[ID(string)=10,5,0]")]
```

The dimension indices of ID are:

```
AQL% SELECT * FROM D:ID;
```

```
[("sample-1"),("sample-10"),("sample-2"),("sample-3"),
("sample-4"),("sample-5"),("sample-6"),("sample-7"),
("sample-8"),("sample-9")]
```

The values of the attribute `val` of `D` are:

```
AQL% SELECT * FROM D;
```

```
[(0),(90),(2),(6),(12),(20),(30),(42),(56),(72)]
```

Note

> In the current version of SciDB, it is not possible to load data directly from an external file into a mapping array.

4.4. Changing Array Names

An array name is used to identify an array in the current SciDB namespace. You can use the AQL `SELECT ... INTO` statement to rename an array.

```
AQL% SELECT * INTO new_A FROM A;
```

This means that both `A` and `new_A` are in the current SciDB namespace. To change an array name and remove the old array name from the current SciDB namespace, use the `rename` command:

```
AFL% rename(new_A, A_backup);
```

You can use the `cast` command to change the name of the array, array attributes, and array dimensions. A single cast can be used to rename multiple items at once, for example, one or more attribute names and/or one or more dimension names. The input array and template arrays should have the same numbers and types of attributes and the same numbers and types of dimensions.

```
AQL% SELECT * FROM show(A);
```

```
[("A<x:double ,err:double > [i=0:99,10,0,j=0:99,10,0]")]
```

This query creates an array `new_A` with attributes `val1` and `val2` and dimensions `x` and `y`:

```
AQL% SELECT * INTO new_A
FROM cast(A,<val1:double,val2:double>
[x=0:99,10,0,y=0:99,10,0]")];
```

4.5. Database Design

4.5.1. Selecting Dimensions and Attributes

An important part of SciDB database design is selecting which values will be dimensions and which will be attributes. Dimensions form a *coordinate* system for the array. Adding dimensions to an array generally improves the performance of many types of queries by speeding up access to array data. Hence, the choice of dimensions depends on the types of queries expected to be run. Some guidelines for choosing dimensions are:

- Dimensions provide selectivity and efficient access to array data. Any coordinate along which selection queries must be performed constitutes a good choice of dimension. If you want to select data subject to certain criteria (for example, all products of price greater than $100 whose brand name is longer than six letters that were sold before 01/01/2010) you may want to design your database such that the coordinates for those parameters are defined by dimensions.

- Array aggregation operators including group-by, window, or grid aggregates specify *coordinates* along which grouping must be performed. Such values must be present as dimensions of the array. For spatial and temporal applications, the space or time dimension is a good choice for a dimension.

- In the case of 2-dimensional arrays common in linear algebra applications, rows represent observations and columns represent variables, factors, or components. Matrix operations such as multiply, covariance, inverse, and best-fit linear equation solution are often performed on a 2-dimensional array structure.

In the absence of these factors, choosing to represent values as attributes is generally a good idea. However, SciDB offers the flexibility to transform data from one array definition to another even after it has been loaded. This step is referred to as *redimensioning* the array and is especially useful when the same data set must be used for different types of analytic queries. Redimensioning is used to transform attributes to dimensions and vice-versa.

4.5.2. Chunk Size Selection

The selection of chunk size in a dimension plays an important role in how well you can query your data. If a chunk size is too large or too small, it will negatively impact performance.

To optimize performance of your SciDB array, you want chunks to contain on order of 10 to 20 MB of data. So, for example, if your data set consists entirely of double-precision numbers, you would want a chunk size that contains somewhere between 500,000 and 1 million elements (assuming 8 bytes for every double-precision number).

When a multiattribute SciDB array is stored, the array attributes are stored in different chunks, a process known as *vertical partitioning*. This is a consideration when you are choosing a chunk size. The size of an individual cell, or the number of attributes per cell, does not determine the total chunk size. Rather, the number of cells in the chunk is the number to use for determining chunk size. For arrays where every dimension has a fixed number of cells and every cell has a value you can do a straightforward calculation to find the correct chunk size.

When the density of the data in a data set is highly skewed, that is, when the data is not evenly distributed along array dimensions, the calculation of chunk size becomes more difficult. The calculation is particularly difficult when it isn't known at array creation time how skewed the data is. In this case, you may want to use SciDB's *repartitioning* functionality to change the chunk size as necessary.

Chapter 5. Loading Data

The key part of setting up your SciDB array is loading your data. This chapter begins by explaining the simplest way to prepare and load a data file. Later, this chapter explains more complicated load scenarios such as parallel loading and loading data from HDF5 and FITS files. Finally, this chapter shows you how to round-trip your data by saving it from a SciDB array back out into a csv file.

The array data model is core to SciDB. When you define a schema for an array you specify which aspects of your data you want to be dimensions and which aspects you want to be attributes based on how you want to conceptualize, access and operate on the data. Before loading data, you have to create an array to load your data into. Refer to the chapter "Creating and Removing SciDB Arrays" for how to create a SciDB array.

5.1. Simple Data Loading

This section describes how to do a simple data load procedure. The steps in simple data loading are:

1. Save your data in comma-separated value (csv) format.
2. Use the csv2scidb command to create a SciDB-formatted load file.
3. Create a 1-dimensional SciDB array to load the data into.
4. Use the LOAD statement to load the data from the SciDB-formatted file into the array.

Consider the 20-line, csv-formatted file `num_data.csv`, the first few lines of which are shown here:

```
val,err
1.48306e+09,1
5.80814e+08,1
1.51079e+09,1
1.16154e+09,1
1.42655e+09,1
1.06341e+09,1
```

This file has two entries per row, where the entries are labelled `val` and `err`. To prepare this file for loading into a SciDB array, use the command `csv2scidb`. The `csv2scidb` command takes multicolumn csv data and transforms it into 1-dimensional arrays with one attribute for every comma-delimited column. The syntax of `csv2scidb` is:

```
csv2scidb [options]  < input-file  > output-file
```

Note

`csv2scidb` is accessed directly at the command-line and not through the `iquery` client. To see the options for `csv2scidb`, type `csv2scidb --help` at the command line. The options for csv2scidb are:

```
-v version of tool
-i PATH input file
-o PATH output file
-a PATH appended output file
-c INT length of chunk
-f INT starting chunk number
```

```
-d char delimiter - default , (comma)
-p STR type pattern - N number, S string, s nullable-string, C char
-s N skip N lines at the beginning of the file
```

This code will transform `num_data.csv` to SciDB load file format:

```
csv2scidb -s 1 -p N < num_data.csv > num_data.scidb
```

The -s flag specifies the number of lines to skip at the beginning of the file. Since the file has a header, you can strip that line, and provide that information as attribute names. The -p flag specifies the type of data you are loading. Possible values are N (number), S (string), s (nullable string), and C (char).

The file `num_data.scidb` looks like this:

```
[
(1.48306e+09,1),
(5.80814e+08,1),
(1.51079e+09,1),
(1.16154e+09,1),
(1.42655e+09,1),
(1.06341e+09,1),
(4.9253e+08,1),
(5.6065e+08,1),
(1.60886e+08,2),
(1.37844e+09,1),
(4.08495e+08,1),
(5.65393e+07,1),
(1.47646e+09,1),
(9.52609e+08,1),
(1.8548e+09,1),
(1.42396e+09,1),
(1.75107e+09,1),
(1.52007e+09,1),
(5.4882e+08,1),
(7.28928e+08,1)
]
```

The square braces show the beginning and end of the array dimension. The parentheses show the cells of the array. There are commas between attributes in cells and cells in the dimension.

To create an array for this data, create an array with 1-dimension. The original data set had two column headers of val and err, so you can name the attributes `val` and `err`:

```
AQL% CREATE ARRAY num_data <val:double,err:double>[i];
```

To load the data into the array `num_data`, use a `LOAD` statement:

```
AQL% LOAD num_data
     FROM 'base-path/doc/user/examples/num_data.scidb';
```

The *`base-path`* is the directory where your SciDB source files are stored.

5.2. Data with Special Values

Suppose you have a load file that is missing some values, like this file, `v4.scidb`:

```
[
 (0,100),(1,99),(2,),(3,97)
]
```

The load file `v4.scidb` has a missing value in the third cell. If you create an array and load this data set, SciDB will substitute 0 for the missing value:

```
AQL% CREATE ARRAY v4 <val1:int8,val2:int8>[i=0:3,4,0];
AQL% LOAD v4 FROM '/examples/v4.scidb';
```

```
[
(0,100),(1,99),(2,0),(3,97)
]
```

To change the default value, that is, the value the SciDB substitutes for the missing data, set the DEFAULT attribute option. This code creates an array `v4_dflt` with default attribute value set to 111:

```
AQL% CREATE ARRAY v4_dflt
     <val1:int8,val2:int8 default 111>[i=0:3,4,0];
AQL% LOAD v4_dflt
     FROM '/examples/v4.scidb';
```

```
[
(0,100),(1,99),(2,111),(3,97)
]
```

Load files may also contain null values, such as in this file, `v4_null.scidb`:

```
[
 (0,100),(1,99),(2,null),(3,97)
]
```

To preserve null values at load time, add the NULL option to the attribute type:

```
AQL% CREATE ARRAY v4_null
<val1:int8,val2:int8 NULL> [i=0:3,4,0];
AQL% LOAD v4_null
     FROM '/example/v4_null.scidb';
```

```
[
(0,100),(1,99),(2,null),(3,97)
]
```

5.3. Parallel Load

The simple data loading procedure serially loads all the data from a single load file. You can set up parallel loading for much faster loading. Parallel loading is more complex because it requires the creation of multiple load files which are chunk-size specific. That is, they are custom constructed around a known chunk size and have to be written with embedded chunk identifiers.

The optional *id* parameter instructs the `LOAD` command to open and load data from a particular instance of SciDB. Possible *id* values are:

id Value	Description
0	Coordinator

1,2, ..., N	*id* of the instance that should perform the load where N is the number of instances in the cluster.
–1	All instances in the cluster. The file path is assumed to be the same at all instances. If an instance cannot open the data file, the load will continue after logging a warning.

For parallel load, each instance must be given distinct chunks. To do this, chunks in the load file must be prefixed with a distinct chunk header that lists the starting dimension values of the chunk.

If your SciDB cluster has 4 instances (with identifiers 1, 2, 3, and 4) and there are 20 chunks, you can place chunks 1–5 on instance 1, chunks 6–10 on instance 2, and so on. The following load command will simultaneously load all 20 chunks into the array and complete 4 times faster.

```
AFL% load (Array, '/tmp/load.data', -1);
```

5.4. Saving Data from a SciDB Array to a File

You can save all or part of the data that is contained in a SciDB array to a file. You can use a **SELECT** statement with the `save` command to save an entire array. For example, consider the following array `random_numbers`:

```
AQL% CREATE ARRAY random_numbers <val:double>[i=0:99,100,0];
AQL% SELECT * INTO random_numbers FROM build(random_numbers,random());
```

You can save the values stored in the array `random_numbers` to a file with the following query:

```
AQL% SAVE random_numbers
     INTO '/tmp/random_data.txt';
```

This statement saves a SciDB-formatted file called `random_data.txt`.

To save the data to `csv` format, set the `iquery` output option to `csv`:

```
% iquery -o csv -q "SAVE random_numbers
     INTO '/tmp/random_data.csv';"
```

```
val,val_rand
1,939618095
2,1011655774
3,3620619210
4,2317057332
5,6137260845
6,10771327980
7,4496569336
8,10364290328
9,2309513805
10,1398261690
```

Note

You will need to enter your iquery statement directly at the command line to change the output option to csv. Type `exit;` at the `AQL%` prompt to stop the current `iquery` session.

Chapter 6. Basic Array Tasks

6.1. Selecting Data From an Array

AQL's Data Manipulation Language (DML) provides queries to access and operate on array data. The basis for selecting data from a SciDB array is the AQL `SELECT` statement with `INTO`, `FROM`, and `WHERE` clauses. The syntax of the `SELECT` statement is:

```
SELECT list | *
[INTO target_array]
FROM array_expression | source_array
[WHERE operator]
```

The arguments for the statement are:

*list|**

`SELECT` *list* can select individual attributes and dimensions, as well as constants and expressions. The wildcard character * means select all attributes.

target_array

The `INTO` clause can create an array to store the output of the query. The target array may also be a pre-existing array in the current SciDB

array_expression|source_array

The `FROM` clause takes a SciDB array as argument. The *array_expression* argument is an expression or subquery that returns an array result. The *source_array* is an array in the current SciDB namespace from which data is being selected.

operator

The expression argument of the `WHERE` clause allows to you specify parameter that filter the query.

6.1.1. The SELECT Statement

AQL expressions in the **`SELECT`** list or the **`WHERE`** clause are standard expressions over the attributes and dimensions of the array. The simplest **`SELECT`** statement is **`SELECT`** `*`, which selects all data from a specified array or array result. Consider two arrays, `A` and `B`:

```
AQL% CREATE ARRAY A <val_a:double>[i=0:9,10,0];
AQL% CREATE ARRAY B <val_b:double>[j=0:9,10,0];
```

These arrays contain data. To see all the data in the array, you can use a `SELECT *` statement with the `scan` command. The `scan(A)` command returns a SciDB array result containing the values of the array data in A. By using `scan(A)` with a `SELECT *` statement, the query will return the entire array result of `scan(A)`:

```
AQL% SELECT * FROM scan(A);
```

```
[(1),(2),(3),(4),(5),(6),(7),(8),(9),(10)]
```

```
AQL% SELECT * FROM scan(B);
```

```
[(101),(102),(103),(104),(105),
(106),(107),(108),(109),(110)]
```

The `show` command returns an array result containing an array's schema. To see the entire schema, use a **`SELECT *`** statement with the `show` command:

```
AQL% SELECT * FROM show(A);
```

```
[("A<val_a:double> [i=0:9,10,0]")]
```

```
AQL% SELECT * FROM show(B);
```

```
[("B<val_b:double> [j=0:9,10,0]")]
```

To refine the result of the `SELECT` statement, use an argument that specifies part of an array result. `SELECT` can take array dimensions or attributes as arguments:

```
SELECT j FROM B;
SELECT val_b FROM B;
```

The `SELECT` statement can also take an expression as an argument. For example, you can scale attribute values by a certain amount:

```
AQL% SELECT val_b/10 FROM B;
```

```
[(10.1),(10.2),(10.3),(10.4),(10.5),
(10.6),(10.7),(10.8),(10.9),(11)]
```

The **`WHERE`** clause can also use built-in functions to create expressions. For example, you can choose just the middle three cells of array B with the greater-than and less-than functions with the `and` operator:

```
SELECT j FROM B WHERE j > 3 and j < 7;
```

```
[(),(),(),(),(4),(5),(6),(),(),()]
```

You can also select an expression of the attribute values for the middle three cells of B by providing an expression for the argument of both **`SELECT`** and **`WHERE`** . For example, this statement returns the square root of the middle three cells of array `B`:

```
SELECT sqrt(val_b) FROM B WHERE j>3 and j<7;
```

```
[(),(),(),(),(10.247),(10.2956),(10.3441),(),(),()]
```

The **`FROM`** clause can take an array or any operation that outputs an array as an argument. The **`INTO`** clause stores the output of a query.

6.2. Array Joins

A join combines two or more arrays typically as a preprocessing step for subsequent operations. The simplest type of join is for two arrays with the same number of dimensions, same dimension starting and ending coordinates, and same chunk size.

The syntax of a simple join statement is:

```
SELECT expressionINTO target_arrayFROM src_array
```

The natural join of these arrays joins the attributes:

```
SELECT * FROM A,B;
```

This join produces:

```
[(1,101),(2,102),(3,103),(4,104),(5,105),
(6,106),(7,107),(8,108),(9,109),(10,110)]
```

You can store the output using the `INTO` clause. For example, this code will store the attribute-attribute join of A and B in array C:

```
AQL% SELECT * INTO C FROM A,B;
```

Arrays do not need to have the same number of attributes to be compatible as long as the dimension and chunk sizes are the same. For example, you can join the two-attribute array C with the one-attribute array B:

```
AQL% SELECT * INTO D FROM C,B;
```

This produces array D with the following schema:

```
[("D<val_a:double,
val_b:double,
val_b_2:double>
[i=0:9,10,0]")]
```

If two arrays have an attribute with the same name, you can select the attributes to use with array dot notation:

```
AQL% SELECT C.val_b + D.val_b FROM C,D;
```

The **`JOIN ... ON`** predicate calculates the multidimensional join of two arrays after applying the constraints specified in the **ON** clause. The **ON** clause lists one or more constraints in the form of equality predicates on dimensions or attributes. The syntax is:

```
SELECT list | *
[
          INTO
           target_array
        ]
FROM array_expression | source_array   JOIN expression | attribute ON dimension |
```

A dimension-dimension equality predicate matches two compatible dimensions, one from each input. The result of this join is an array with higher number of dimensions -- combining the dimensions of both its inputs, less the matched dimensions. If no predicate is specified, the result is the full cross product array.

An attribute predicate in the ON clause is used to filter the output of the multidimensional array.

For example, consider a 2-dimensional array `m3x3`schema and attributes values:

```
[("m3x3<a:double> [i=1:3,3,0,j=1:3,3,0]")]
[
[(4),(5),(6)],
[(7),(8),(9)],
[(10),(11),(12)]
]
```

And a 1-dimensional array `vector3`schema and attribute values:

```
[("vector3<b:double> [k=1:3,3,0]")]
[(21),(20.5),(20.3333)]
```

A dimension join returns a 2-dimensional array with coordinates `{i, j}` in which the cell at coordinate `{i, j}` combines the cell at `{i, j}` of `m3x3` with the cell at coordinate `{k=j}` of `vector3`:

```
AQL% SELECT * FROM m3x3 JOIN vector3 ON m3x3.j = vector3.k;
```

```
[
[(4,21),(5,20.5),(6,20.3333)],
[(7,21),(8,20.5),(9,20.3333)],
[(10,21),(11,20.5),(12,20.3333)]
]
```

6.3. Aliases

AQL provides a way to refer to arrays and array attributes in a query via aliases. These are useful when using the same array repeatedly in an AQL statement, or when abbreviating a long array name. Aliases are created by adding an "as" to the array or attribute name, followed by the alias. Future references to the array can then use the alias. Once an alias has been assigned, all attributes and dimensions of the array can use the fully qualified name using the dotted naming convention.

```
AQL% SELECT data.i*10 FROM A AS data WHERE A.i < 5;
```

```
[(0),(10),(20),(30),(40),(),(),(),(),()]
```

6.4. Nested Subqueries

You can nest AQL queries to refine query results.

For example, you can nest `SELECT` statements before a `WHERE` clause to select a subset of the query output. For example, this query

1. Sums two attributes from two different arrays and stores the output in an alias,

2. Selects the cells with indices greater than 5, and

3. Squares the result.

```
AQL% SELECT pow(c,2) FROM
   (SELECT A.val_a + B.val_b AS c FROM A,B)  WHERE i > 5;
```

```
[(),(),(),(),(),(),(12996),(13456),(13924),(14400)]
```

6.5. Data Sampling

SciDB provides operations to sample array data. The `bernoulli` command allows you to select a subset of array cells based upon a given probability. For example, you can use the `bernoulli` operator to randomly sample data from an array one element at a time. The syntax of `bernoulli` is:

```
bernoulli(array, probability:double  [, seed:int64])
```

The `sample` command allows you to randomly sample data one array chunk at a time:

```
sample(array, probability:double  [, seed:int64])
```

The probability is a double between 0 and 1. The commands work by generating a random number for each cell or chunk in the array and scaling it to the probability. If the random number is within the probability, the cell/chunk is included. Both commands allow you to produce repeatable results by seeding the random number generator. All calls to the random number generator with the same seed produce the same random number. Seeds must be a 64-bit integer.

Chapter 7. Aggregates

SciDB supports commands to group data from an array and calculate summaries over those groups. These commands are called *aggregates*. SciDB provides the following types of aggregates based on how data is grouped:

- *Grand aggregates* compute aggregates over entire arrays.
- *Group-by aggregates* compute summaries by grouping array data by dimension values.
- *Grid aggregates* compute summaries for nonoverlapping subarrays.
- *Window aggregates* compute summaries over a moving window in an array.

This chapter uses example arrays `m4x4` and `m4x4_2attr`, which have the following schemas and contain the following values:

```
AFL% show(m4x4);
```

```
[("m4x4<attr1:double> [x=0:3,4,0,y=0:3,4,0]")]
```

```
AFL% scan(m4x4);
```

```
[
[(0),(1),(2),(3)],
[(4),(5),(6),(7)],
[(8),(9),(10),(11)],
[(12),(13),(14),(15)]
]
```

```
AFL%  show(m4x4_2attr);
```

```
[("m4x4_2attr<attr1:double,attr2:double>
[x=0:3,4,0,y=0:3,4,0]")]
```

```
AFL% scan(m4x4_2attr);
```

```
[
[(0,0),(1,2),(2,4),(3,6)],
[(4,8),(5,10),(6,12),(7,14)],
[(8,16),(9,18),(10,20),(11,22)],
[(12,24),(13,26),(14,28),(15,30)]
]
```

SciDB offers the following built-in aggregates.

Aggregate Function	Definition
`avg`	Average value
`count`	Number of nonempty elements (array count) and non-null elements (attribute count).
`max`	Largest value
`min`	Smallest value
`sum`	Sum of all elements

stdev	Standard deviation
var	Variance

7.1. Grand Aggregates

Grand aggregates in SciDB calculate aggregates or summaries of attributes across an entire array. The syntax of the **SELECT** statement with built-in summary functions is:

```
SELECT function(attribute),function(attribute),...
INTO dst-array
FROM src-array | array-expression
WHERE where-expression
```

The output is a SciDB array with one attribute named for the summary type in the query and array dimensions determined by the size and shape of the result.

For example, to select the maximum and the minimum values of the attribute `attr1` of the array `m4x4`:

```
AQL% SELECT max(attr1),min(attr1) FROM m4x4;
```

```
[(15,0)]
```

You can store the output of a query into a destination array, `m4x4_max_min` with an **INTO** clause:

```
AQL% SELECT max(attr1),min(attr1)
INTO m4x4_max_min
FROM m4x4;
```

The destination array `m4x4_max_min` has schema:

```
[("m4x4_max_min<max:double NULL,min_1:double NULL> [i=0:0,1,0]")]
```

To select the maximum value from the attribute val of `m4x4_2attr` and the minimum value from the attribute `val2` of `m4x4_2attr`:

```
AQL% SELECT max(attr2),min(attr)
FROM m4x4_2attr;
```

```
[(30,0)]
```

Note

In the special case of a one-attribute array, you can omit the attribute name. For example, to select the maximum value from the attribute `attr1` of the array `m4x4`, use the AQL **SELECT** statement:

```
AQL% SELECT max(m4x4);
```

```
[(15)]
```

The AFL `aggregate` operator also computes grand aggregates. To select the maximum value from the attribute val of `m4x4_2attr` and the minimum value from the attribute `val2` of `m4x4_2attr`:

```
AFL% aggregate(m4x4_2attr, max(attr2),min(attr1));
```

```
[(30,0)]
```

SciDB functions exclude null-valued data. For example, consider the following array `m4x4_null`:

```
[
[(null),(null),(null),(null)],
[(null),(null),(null),(null)],
[(0),(0),(0),(0)],
[(null),(null),(null),(null)]
]
```

The syntaxes `count(attr1)` and `count(*)` return different results:

```
AQL% SELECT count(attr1) AS a, count(*) AS b
FROM m4x4_null;
```

```
[(4,16)]
```

One syntax, `count(attr1)`, shows only cells that have values that are. The other syntax, `count(*)`, shows cells whose values are NULL and cells whose values are.

7.2. Group-By Aggregates

Group-by aggregates allow you to group array data by array dimensions and summarize the data in those groups.

AQL `GROUP BY` aggregates take a list of dimensions as the grouping criteria and compute the aggregate function for each group. The result is an array with same dimensions as the source array (without the group-by dimensions) and a single attribute per aggregate requested. The syntax of the **`SELECT`** statement for a group-by aggregate is:

```
SELECT function(attribute), function(attribute), ...
  INTO dst-array
  FROM src-array | array-expression
  WHERE where-expression
  GROUP BY dimension, dimension, ...;
```

For example, this query selects the maximum value from the attribute `val` of array `m4x4` grouped by dimension `x`:

```
AQL% SELECT max(attr1)
     FROM m4x4
     GROUP BY x;
```

This query outputs:

```
[(3),(7),(11),(15)]
```

which has schema:

```
<max:double NULL> [x=0:3,4,0]
```

This query selects the maximum values from attribute `attr1` of array `m4x4` grouped by dimension `y`:

```
AQL% SELECT max(attr1) FROM m4x4 GROUP BY y;
```

```
[(12),(13),(14),(15)]
```

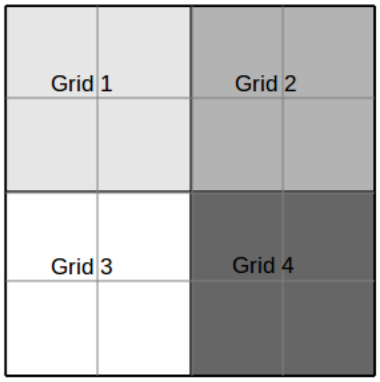
The AFL `aggregate` operator takes dimension arguments to support group-by functionality. This query selects the maximum values from the dimension `y` and attribute `val` from the array `m4x4` using AFL:

```
AFL% aggregate(m4x4, max(attr1),y);
```

```
[(12),(13),(14),(15)]
```

7.3. Grid Aggregates

A grid aggregate selects nonoverlapping subarrays from an existing array and calculates an aggregate of each subarray. For example, if you have a 4x4 array, you can create 4 nonoverlapping 2x2 regions and calculate an aggregate for those regions. The array `m4x4` would be divided into 2x2 grids as follows:



The syntax of a grid aggregate statement is:

```
SELECT function(attribute), function(attribute), ...
INTO dst-array
FROM src-array | array-expression
WHERE where-expression
REGRID dimension1-size, dimension2-size, ...;
```

For example, this statement finds the maximum and minimum values for each of the four grids in the previous figure:

```
AQL% SELECT max(attr1), min(attr1) FROM m4x4 REGRID 2,2;
```

```
[
[(5,0),(7,2)],
[(13,8),(15,10)]
]
```

This output has schema:

```
<max:double NULL,min_1:double NULL> [x=0:1,2,0,y=0:1,2,0]
```

In AFL, you can use the `regrid` operator:

```
AFL% regrid(m4x4, 2,2, max(attr1),min(attr1));
```

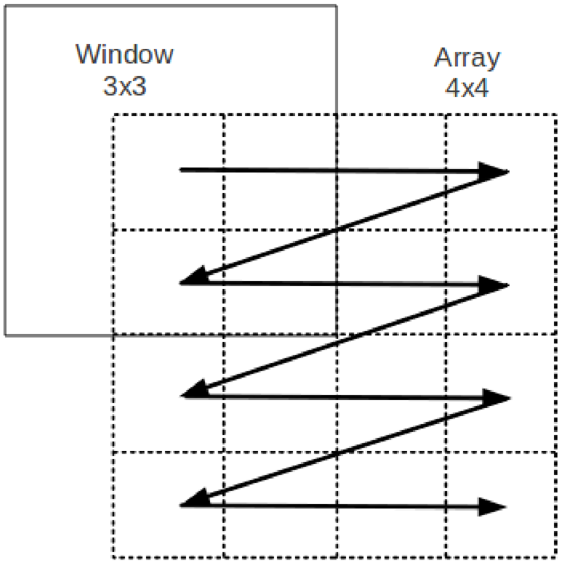
```
[
[(5,0),(7,2)],
[(13,8),(15,10)]
]
```

7.4. Window Aggregates

Window aggregates allow you to specify groups with a moving window. The window is defined by a size in each dimension. The window centroid starts at the first array element. The grouping starts at the first element of the array and moves in stride-major order from the lowest to highest value in each dimension. The syntax of a window aggregate statement is:

```
SELECT function(attribute), function(attribute), ...
INTO dst-array
FROM src-array | array-expression
WHERE where-expression
WINDOW dimension1-size, dimension2-size, ...;
```

For example, you can use a window to calculate a running sum for a 3x3 window on array `m4x4`.



In AQL, you would use this statement:

```
AQL% SELECT sum(attr1)
FROM m4x4
WINDOW 3,3;
```

Which returns values:

```
[
[(10),(18),(24),(18)],
[(27),(45),(54),(39)],
[(51),(81),(90),(63)],
[(42),(66),(72),(50)]
]
```

with schema:

```
<sum:double NULL> [x=0:3,4,0,y=0:3,4,0]
```

Since the window centroid starts at cell {0,0}, the region of the window that is outside the array boundary is not counted in the aggregation.

In AFL, you would use the `window` operator:

```
AFL% window(m4x4,3,3,sum(attr1));
```

```
[
[(10),(18),(24),(18)],
[(27),(45),(54),(39)],
[(51),(81),(90),(63)],
[(42),(66),(72),(50)]
]
```

Chapter 8. Updating Your Data

SciDB uses a "no overwrite" storage model. No overwrite means that data in an array can be updated but previous values can be accessed as long as the array exists in the SciDB namespace. Every time you update data in an array, SciDB creates a new array version, much like source control systems for software development.

8.1. The UPDATE ... SET statement

To update data in an existing SciDB array, use the statement:

```
UPDATE array SET "attr = expr", ... [ WHERE condition ];
```

Consider the following 2-dimensional array, `m4x4`:

```
[("m4x4<val:double> [x=0:3,4,0,y=0:3,4,0]")]
[
[(0),(1),(2),(3)],
[(4),(5),(6),(7)],
[(8),(9),(10),(11)],
[(12),(13),(14),(15)]
]
```

To change every value in `val` to its additive inverse:

```
UPDATE m4x4 SET val=-val;
```

```
[
[(0),(-1),(-2),(-3)],
[(-4),(-5),(-6),(-7)],
[(-8),(-9),(-10),(-11)],
[(-12),(-13),(-14),(-15)]
]
```

The **WHERE** clause lets you choose attributes based on conditions. For example, you can select just cells with absolute values greater than 5 to set to their multiplicative inverse:

```
UPDATE m4x4 SET val=pow(val,-1) WHERE abs(val) > 5;
```

```
[
[(0),(-1),(-2),(-3)],
[(-4),(-5),(-0.166667),(-0.142857)],
[(-0.125),(-0.111111),(-0.1),(-0.0909091)],
[(-0.0833333),(-0.0769231),(-0.0714286),(-0.0666667)]
]
```

8.2. Array Versions

When an array is updated, a new array version is created. SciDB stores the array versions. For example, in the previous section, SciDB stored every version of m4x4 created by the **UPDATE** command. You can see these versions with `versions`:

```
AQL% SELECT * FROM versions(m4x4);
```

```
[(1,"2012-02-03 17:20:50"),
(2,"2012-02-06 14:51:20"),
(3,"2012-02-06 14:52:33")]
```

You can see the contents of any previous version of the array by using the version number:

```
AQL% SELECT * FROM scan(m4x4@1);
[
[(0),(1),(2),(3)],
[(4),(5),(6),(7)],
[(8),(9),(10),(11)],
[(12),(13),(14),(15)]
]
```

Or the array timestamp:

```
AQL% SELECT * FROM scan(m4x4@datetime('2012-02-03 17:20:50'));
[
[(0),(1),(2),(3)],
[(4),(5),(6),(7)],
[(8),(9),(10),(11)],
[(12),(13),(14),(15)]
]
```

You can use the array version name in any query. The unqualified name of the array always refers to the most recent version as of the start of the query.

Chapter 9. Changing Array Schemas: Transforming Your SciDB Array

9.1. Redimensioning an Array

A common use case for creating and loading SciDB arrays is using data from a data warehouse. This data set may be very large and formatted as a csv file. You can use the csv2scidb utility to convert a csv file to the 1-dimensional array format and load the file into a SciDB array. Once you have a 1-dimensional SciDB array, you can redimension the array to convert the attributes to dimensions.

For example, suppose you have a csv file like this:

```
s,p,val
"device-0","probe-0",0.01
"device-1","probe-0",2.04
"device-2","probe-0",6.09
"device-3","probe-0",12.16
"device-4","probe-0",20.25
"device-0","probe-1",30.36
"device-1","probe-1",42.49
"device-2","probe-1",56.64
"device-3","probe-1",72.81
"device-4","probe-1",91
"device-0","probe-2",111.21
"device-1","probe-2",133.44
"device-2","probe-2",157.69
"device-3","probe-2",183.96
"device-4","probe-2",212.25
"device-0","probe-3",242.56
"device-1","probe-3",274.89
"device-2","probe-3",309.24
"device-3","probe-3",345.61
"device-4","probe-3",384
"device-0","probe-4",424.41
"device-1","probe-4",466.84
"device-2","probe-4",511.29
"device-3","probe-4",557.76
"device-4","probe-4",606.25
```

This data has three columns, two of which are stings and one which is a floating-point number. The column headers are 's','p',and 'val'. To load this data set, create a 1-dimensional SciDB array with three attributes and load the data into it. For this example, the array is named expo. The dimension name is i, the dimension size is 25, the chunk size is 5. The attributes are s, of type string, p of type string, and val of type double.

```
SELECT * FROM show(expo);
```

```
[("expo<s:string,p:string,
val:double> [i=1:25,5,0]")]
```

When you examine the data, notice that it could be expressed in a 2-dimensional format like this:

	probe-0	probe-1	probe-2	probe-3	probe-4

device-0	0.01	30.36	111.21	242.56	424.41
device-1	2.04	42.49	133.44	274.89	466.84
device-2	6.09	56.64	157.69	309.24	511.29
device-3	12.16	72.81	183.96	345.61	557.76
device-4	20.25	91	212.25	384	606.25

SciDB allows you to redimension the data so that you can store it in this 2-dimensional format. First, create an array with 2 dimensions:

```
AFL% create array Dsp
<val:double>
[s(string)=5,5,0, p(string)=5,5,0];
```

Each of the dimensions is of size 5, corresponding to a dimension in the 5-by-5 table. Now, you can use the redimension_store operator to redimension the array expo into the array Dsp:

```
AFL% redimension_store(expo, Dsp);
```

```
[
[(0.01),(30.36),(111.21),(242.56),(424.41)],
[(2.04),(42.49),(133.44),(274.89),(466.84)],
[(6.09),(56.64),(157.69),(309.24),(511.29)],
[(12.16),(72.81),(183.96),(345.61),(557.76)],
[(20.25),(91),(212.25),(384),(606.25)]
]
```

Now the data is stored so that sample and probe numbers are the dimensions of the array. This means that you can use the dimension indices to select data from the array. For example, to select the second sample from the third probe, use the dimension indices:

```
AQL% SELECT val FROM Dsp  WHERE s='device-2' and p='probe-3';
```

Redimensioning is a powerful tool when you want to do array aggregation along the coordinate axes of a data set. For example, you can find the average value of a sample for each probe. This would be equivalent to finding the average of every row in the table:

```
create array Ds
<av:double NULL>[s(string)=5,5,0];
redimension_store(expo, Ds, true, avg(val) as av);
```

Or, you can find the average value of all the samples for a single probe. This would be equivalent to finding the average of every column in the table:

```
AFL% create array Dp
<av:double NULL>[p(string)=5,5,0];
AFL% redimension_store(expo, Dp, true, avg(val) as av);
```

9.2. Array Transformations

Once you have created, loaded, and redimensioned a SciDB array, you may want to change some aspect of that array. SciDB offers functionality to transform the elements of the array schema (attributes and dimensions).

The array transformation operations produce a result array with a new schema. They do not modify the source array. Array transformation operations have the signature:

```
SELECT * FROM operation(source_array,parameters)
```

This query outputs a SciDB array. To store that array result, use the `INTO` clause:

```
SELECT * INTO result_array FROM operation(source_array,parameters)
```

9.2.1. Rearranging Array Data

SciDB offers functionality to rearrange an array data:

- **Reshaping** an array by changing the dimension sizes. is performed with the `reshape` command.
- **Unpacking** a multidimensional array into a 1-dimensional array is performed with the `unpack` command.
- **Reversing** the cells in a dimension is performed with the `reverse` command.

For example, you might want to reshape your array from an *m*-by-*n* array to a 2*m*-by-*n*/2 array. The `reshape` command allows you to transform an array into another compatible schema. Consider a 4-by-4 array, `m4x4`:

```
AFL% show(m4x4);scan(m4x4);
[("m4x4<val:double> [i=0:3,4,0,j=0:3,4,0]")]
[
[(0),(1),(2),(3)],
[(4),(5),(6),(7)],
[(8),(9),(10),(11)],
[(12),(13),(14),(15)]
]
```

As long as the two array schemas have the same number of cells, you can use reshape to transform one schema into the other. A 4-by-4 array has 16 cells, so you can use any schema with 16 cells, such as 8-by-2, as the new schema:

```
AQL% SELECT * INTO m8x2 FROM
reshape(m4x4,<val:double>
[i2=0:7,8,0,j2=0:1,2,0]);
```

```
[
[(0),(1)],
[(2),(3)],
[(4),(5)],
[(6),(7)],
[(8),(9)],
[(10),(11)],
[(12),(13)],
[(14),(15)]
]
```

A special case of reshaping is unpacking a multidimensional array to a 1-dimensional array. When you unpack an array, the coordinates of the array cells are stored in the attributes to the result array. This is particularly useful is you are planning to save your data to csv format.

The unpack command takes the second and higher dimensions of an array and transforms them into attributes along the first dimension. The result array consists of the dimension values of the input array with the attribute values from the corresponding cells appended. So, an attribute value val that was in row 1, column 3 of a 2-dimensional array will be transformed into a cell with attribute values 1,3,val. For example, a 2-dimensional, 1-attribute array will output a 1-dimensional, 3-attribute array as follows:

```
AQL% SELECT * FROM show(m3x3);
```

```
[("m3x3<val:double> [i=0:2,3,0,j=0:2,3,0]")]
```

```
AQL% SELECT * INTO m1 FROM unpack(m3x3,k);
```

```
[(0,0,0),
(0,1,1),
(0,2,2),
(1,0,3),
(1,1,4),
(1,2,5),
(2,0,6),
(2,1,7),
(2,2,8),
(0,0,0),
(0,0,0),
(0,0,0)]
```

```
AQL% SELECT * FROM show(m1);
```

```
[("m1<i:int64,
j:int64,
val:double>
[val1=0:15,4,0]")]
```

You can reverse the ordering of the data in each dimension of an array with the reverse command:

```
AFL% show(m3x3);scan(m3x3);
```

```
[("m3x3<val:double> [i=0:2,3,0,j=0:2,3,0]")]
[[(0),(1),(2)],[(3),(4),(5)],[(6),(7),(8)]]
```

```
AQL% SELECT * FROM reverse(m3x3);
```

```
[
[(8),(7),(6)],
[(5),(4),(3)],
[(2),(1),(0)]]
```

9.2.2. Reduce an Array

One common array task is selecting subsets of an array. SciDB allows you to reduce an array to contiguous subsets of the array cells or noncontiguous subsets of the array's cells.

- A **subarray** is a contiguous block of cells from an array. This action is performed by the subarray command.
- An array **slice** is a subset of the array defined by planes of the array. This action is performed by the slice command.

- A dimension can be winnowed or **thinned** by selecting data at intervals along its entirety. This action is performed by the `thin` command.

You can select part of an existing array into another array with the `subarray` command. For example, you can select a 2-by-2 array of the last two values from each dimension of the array `m4x4` with the following `subarray` command:

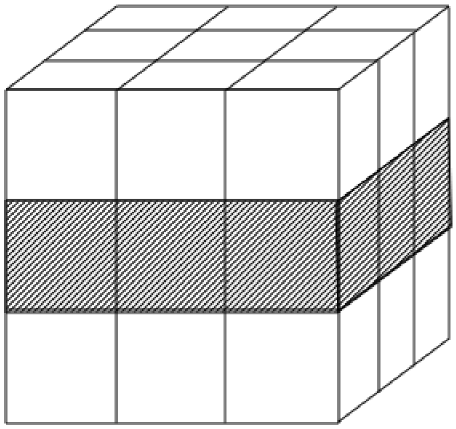
```
AFL% show(m4x4);scan(m4x4);
[("m4x4<val:double>
[i=0:3,4,0,j=0:3,4,0]")]
```

```
[
[(0),(1),(2),(3)],
[(4),(5),(6),(7)],
[(8),(9),(10),(11)],
[(12),(13),(14),(15)]
]
```

```
AQL% SELECT * FROM subarray(m4x4,2,2,3,3);
```

```
[
[(10),(11)],
[(14),(15)]
]
```

If you have a 3-dimensional array, you might want to select just a flat 2-dimensional slice, as like the cross-hatched section of this image:



For example, you can select the data in a horizontal slice in the middle of a 3-dimensional array `m3x3x3` by using the `slice` command and specifying the value for dimension `k`:

```
AFL% show(m3x3x3);scan(m3x3x3);
[("m3x3x3<val:double>
[i=0:2,3,0,j=0:2,3,0,k=0:2,3,0]")]
```

```
[
[[(0),(1),(2)],
[(4),(5),(6)],
[(8),(9),(10)]
],
[[(7),(8),(9)],
[(11),(12),(13)],
[(15),(16),(17)]
],
[
[(14),(15),(16)],
[(18),(19),(20)],
[(22),(23),(24)]
]
]
```

```
AFL% slice(m3x3x3,k,1);
```

```
[
[(1),(5),(9)],
[(8),(12),(16)],
[(15),(19),(23)]
]
```

You may want to sample data uniformly across an entire dimension. The `thin` command selects elements from given array dimensions at defined intervals. For example, you can select every other element from every other row:

```
AFL% show(m4x4);scan(m4x4);
[("m4x4<val:double>
[i=0:3,4,0,j=0:3,4,0]")]
```

```
[
[(0),(1),(2),(3)],
[(4),(5),(6),(7)],
[(8),(9),(10),(11)],
[(12),(13),(14),(15)]
]
```

```
AQL% SELECT * FROM thin(m4x4,1,2,0,2);
```

```
[
[(4),(6)],
[(12),(14)]
]
```

9.3. Changing Array Attributes

An array's attributes contain the data stored in the array. You can transform attributes by

- Changing the name of the attribute.
- Adding an attribute.
- Changing the order of attributes in a cell.
- Deleting an attribute.

You can change the name of an attribute with the `attribute_rename` command:

```
AQL% SELECT * INTO m3x3_new  FROM attribute_rename(m3x3,val,val2);
```

```
[
[(0),(1),(2)],
[(3),(4),(5)],
[(6),(7),(8)]
]
```

```
AQL% SELECT * FROM show(m3x3_new);
```

```
[("m3x3_new<val2:double> [i=0:2,3,0,j=0:2,3,0]")]
```

You can add attributes to an existing array with the `apply` command:

```
AQL% SELECT *
    INTO m3x3_new_attr
    FROM apply(m3x3,val2,val+10,val3,pow(val,2));
```

```
[
[(0,10,0),(1,11,1),(2,12,4)],
[(3,13,9),(4,14,16),(5,15,25)],
[(6,16,36),(7,17,49),(8,18,64)]
]
```

```
AQL% SELECT * FROM show(m3x3_new_attr);
```

```
[("m3x3_new_attr
<val:double,val2:double,val3:double>
[i=0:2,3,0,j=0:2,3,0]")]
```

You can select a subset of an array's attributes and return them in any order with the `project` command.

```
AQL% SELECT * FROM project(m3x3_new_attr,val3,val2);
```

```
[
[(0,10),(1,11),(4,12)],
[(9,13),(16,14),(25,15)],
[(36,16),(49,17),(64,18)]
]
```

9.4. Changing Array Dimensions

9.4.1. Changing Chunk Size

If you have created an array with a particular chunk size and then later find that you need a different chunk size, you can use the `repart` command to change the chunk size. For example, suppose you have an array that is 1000-by-1000 with chunk size 100 in each dimension:

```
AQL% SELECT * FROM show(chunks);
```

```
[("chunks<val1:double,val2:double>
[i=0:999,100,0,j=0:999,100,0]")]
```

You can repartition the chunks to be 10 along one dimension and 1000 in the other:

```
AQL% SELECT *
     INTO chunks_part
     FROM repart(chunks,<val1:double,val2:double>
[i=0:999,10,0,j=0:999,1000,0]);
```

```
AQL% SELECT * FROM show(chunks_part);
```

```
[("chunks_part<val1:double,
val2:double>
[i=0:999,10,0,j=0:999,1000,0]")]
```

Repartitioning is also important if you want the change the chunk overlap to speed up nearest-neighbor or window aggregate queries.

```
AQL% SELECT *
     INTO chunks_overlap
      FROM repart(chunks,<val1:double,val2:double>
     [i=0:999,100,10,j=0:999,100,10]);
```

9.4.2. Appending a Dimension

You may need to append dimensions to existing arrays, particularly when you want to do more complicated tranformations to your array. This example demonstrates how you can take slices from an existing array and then reassemble them into a array with a different schema. Consider the following 2-dimensional array:

```
AFL% show(Dsp);scan(Dsp);
```

```
[("Dsp<val:double,
empty_indicator:indicator>
[s(string)=5,5,0,p(string)=5,5,0]")]

[
[(0.01),(30.36),(111.21),(242.56),(424.41)],
[(2.04),(42.49),(133.44),(274.89),(466.84)],
[(6.09),(56.64),(157.69),(309.24),(511.29)],
[(12.16),(72.81),(183.96),(345.61),(557.76)],
[(20.25),(91),(212.25),(384),(606.25)]
]
```

Suppose you want to examine a sample plane from each dimension of the array. You can use the slice command to select array slices from array `Dsp`:

```
AQL% SELECT * INTO Dsp_slice_0  FROM slice(Dsp,s,'device-0');

AQL% SELECT * INTO Dsp_slice_1  FROM slice(Dsp,s,'device-1');

AQL% SELECT * INTO Dsp_slice_2  FROM slice(Dsp,s,'device-2');
```

The slices are 1-dimensional.

```
AQL% SELECT * FROM show(Dsp_slice_0);
```

```
[("Dsp_slice_0
<val:double,
empty_indicator:indicator>
[p(string)=5,5,0]")]
```

Concatenating these slices will create a 1-d array:

```
AQL% SELECT * INTO Dsp_1d FROM concat(Dsp_slice_0,Dsp_slice_2);
AQL% SELECT * FROM show(Dsp_1d);
```

```
[("Dsp_1d<val:double,
empty_indicator:indicator>
[p=0:9,5,0]")]
```

To concatenate these arrays into a 2-dimensional array, you need to add a dimension to both. The `adddim` command will add a stub dimension to the array to increase its dimensionality.

```
AQL% SELECT * INTO Dsp_new
FROM concat(adddim(Dsp_slice_0, s),
adddim(Dsp_slice_2, s));
AQL% SELECT * FROM show(Dsp_new);
```

```
[("Dsp_new<val:double,
empty_indicator:indicator>
[s=0:1,1,0,p(string)=5,5,0]")]
```

Chapter 10. SciDB Aggregate Reference

This chapter lists SciDB aggregates. Aggregates take as input a set of 1 or more values and return a scalar value. SciDB aggregates have the syntax aggregate_call_N where an aggregate call is one of the following:

- `aggregate_name(attribute_name)`
- `aggregate_name(expression)`

  Note: the `aggregate_name(expression)` syntax exists only in AQL.

Aggregate calls can occur in AQL and AFL statements as follows:

AQL syntaxes

```
SELECT aggregate_call_1[,aggregate_call_2,...,aggregate_call_N]
FROM array;

SELECT aggregate_call_1[,aggregate_call_2,...,aggregate_call_N]
FROM array GROUP BY dimension1[,dimension2];

SELECT aggregate_call_1[,aggregate_call_2,...,aggregate_call_N]
FROM array WHERE expression;

SELECT aggregate_call_1[,aggregate_call_2,...,aggregate_call_N]
FROM array REGRID dimension_1, dimension_2,...

SELECT aggregate_call_1[,aggregate_call_2,...,aggregate_call_N]
FROM array WINDOW window_dim_1, window_dim_2,...
```

AFL syntaxes

```
aggregate(array, aggregate_call_1
[, aggregate_call_2,... aggregate_call_N]
[,dimension_1, dimension_2,...])

window(array,grid_1,grid_2,...,grid_N,
aggregate_call_1 [,aggregate_call_2,...,aggregate_call_N]);

regrid(array,grid_1,grid_2,...,grid_N,
aggregate_call_1[,aggregate_call_2,...,aggregate_call_N]);
```

Name

avg — Average (mean) aggregate

Synopsis

```
SELECT avg(attribute) FROM array;
```

```
aggregate(array,avg(attribute)[,dimension_1,dimension_2,...]
```

Summary

The avg aggregate takes a set of scalar values from an array attribute and returns the average of those values.

Example

This example finds the average of every column of a 3×3 matrix.

1. Create a matrix m3x3:

   ```
   CREATE ARRAY m3x3<val:double>[i=0:2,3,0,j=0:2,3,0];
   ```

2. Put values of 0–8 into m3x3:

   ```
   store(build(m3x3,i*3+j),m3x3);
   ```

   ```
   [
   [(0),(1),(2)],
   [(3),(4),(5)],
   [(6),(7),(8)]
   ]
   ```

3. Find the average of every column of m3x3:

   ```
   aggregate(m3x3,val,j)
   ```

   This query returns:

   ```
   [(3),(4),(5)]
   ```

Name

count — Count nonempty elements aggregate

Synopsis

```
SELECT count(attribute) FROM array;

aggregate(array,count(attribute)[,dimension_1,dimension_2,...)]
```

Summary

The count aggregate counts nonempty elements of an array's attributes.

Example

This example finds the number of nonempty cells in a 3×3 matrix.

1. Create a matrix m3x3:

   ```
   CREATE ARRAY m3x3<val:double>[i=0:2,3,0,j=0:2,3,0];
   ```

2. Put values 1 along the diagonal of m3x3 and leave the remaining cells empty:

   ```
   store(build_sparse(m3x3,i=j,1),m3x3);
   ```

3. Find the number of nonempty cells in the array:

   ```
   aggregate(m3x3,count(val));
   ```

   This query returns:

   ```
   [(6)]
   ```

Name

max — Maximum value aggregate

Synopsis

```
SELECT max(attribute) FROM array;
```

```
aggregate(array,max(attribute)[,dimension_1,dimension_2,...]
```

Summary

Example

This example finds the maximum of every column of a 3×3 matrix.

1. Create a matrix m3x3:

   ```
   CREATE ARRAY m3x3<val:double>[i=0:2,3,0,j=0:2,3,0];
   ```

2. Put values of 0–8 into m3x3:

   ```
   store(build(m3x3,i*3+j),m3x3);
   ```

   ```
   [
   [(0),(1),(2)],
   [(3),(4),(5)],
   [(6),(7),(8)]
   ]
   ```

3. Find the maximum value of each column:

   ```
   aggregate(m3x3,max(val),j);
   ```

   This query returns:

   ```
   [(6),(7),(8)]
   ```

Name

min — Minimum value aggregate

Synopsis

```
SELECT min(attribute) FROM array;
```

```
aggregate(array,min(attribute)[,dimension_1,dimension_2,...]
```

Summary

Example

This example finds the minimum of every column of a 3×3 matrix.

1. Create a matrix m3x3:

   ```
   CREATE ARRAY m3x3<val:double>[i=0:2,3,0,j=0:2,3,0];
   ```

2. Put values of 0–8 into m3x3:

   ```
   store(build(m3x3,i*3+j),m3x3);
   ```

   ```
   [
   [(0),(1),(2)],
   [(3),(4),(5)],
   [(6),(7),(8)]
   ]
   ```

3. Find the minimum value of every column of m3x3:

   ```
   aggregate(m3x3,min(val),j);
   ```

   This query returns:

   ```
   [(0),(1),(2)]
   ```

Name

stdev — Standard deviation aggregate

Synopsis

```
SELECT stdev(attribute) FROM array;
```

```
aggregate(array,stdev(attribute)[,dimension_1,dimension_2,...]
```

Summary

Example

This example finds the standard deviation of every column of a 3×3 matrix.

1. Create a matrix m3x3:

   ```
   CREATE ARRAY m3x3<val:double>[i=0:2,3,0,j=0:2,3,0];
   ```

2. Put random values between 1 and 9 into m3x3:

   ```
   store(build(m3x3,random()%10/1.0),m3x3);
   ```

   This query outputs:

   ```
   [
   [(2),(8),(0)],
   [(5),(2),(6)],
   [(2),(0),(2)]
   ]
   ```

3. Find the standard deviation of every column of m3x3:

   ```
   aggregate(m3x3,stdev(val),j);
   ```

   This query returns:

   ```
   [(1.73205),(4.16333),(3.05505)]
   ```

Name

sum — Sum aggregate

Synopsis

```
SELECT sum(attribute) FROM array;
```

```
aggregate(array,sum(attribute)[,dimension_1,dimension_2,...]
```

Summary

The sum aggregate calculates the cumulative sum of a group of values.

Example

This example finds the sum of every column of a 3×3 matrix.

1. Create a matrix m3x3:

   ```
   CREATE ARRAY m3x3<val:double>[i=0:2,3,0,j=0:2,3,0];
   ```

2. Put values of 0–8 into m3x3:

   ```
   store(build(m3x3,i*3+j),m3x3);
   ```

   ```
   [
   [(0),(1),(2)],
   [(3),(4),(5)],
   [(6),(7),(8)]
   ]
   ```

3. Find the sum of each column in m3x3:

   ```
   aggregate(m3x3,sum(val),j)
   ```

   This query returns:

   ```
   [(9),(12),(15)]
   ```

Name

var — Variance aggregate

Synopsis

```
SELECT var(attribute) FROM array;
```

```
aggregate(array,var(attribute)[,dimension_1,dimension_2,...]
```

Summary

The var aggregate returns the variance of a set of values.

Example

This example finds the variance of every column of a 3×3 matrix.

1. Create a matrix m3x3:

   ```
   CREATE ARRAY m3x3<val:double>[i=0:2,3,0,j=0:2,3,0];
   ```

2. Put random values between 1 and 9 into m3x3:

   ```
   store(build(m3x3,random()%10/1.0),m3x3);
   ```

   This query returns:

   ```
   [
   [(2),(8),(0)],
   [(5),(2),(6)],
   [(2),(0),(2)]
   ]
   ```

3. Find the variance for each column of m3x3:

   ```
   aggregate(m3x3,var(val),j)
   ```

   This query returns:

   ```
   [(3),(17.3333),(9.33333)]
   ```

Chapter 11. SciDB Function Reference

Table 11.1. List of SciDB Functions

Function Name	Description	Category
%	Remainder	Arithmetic
*	Multiplication	Arithmetic
+	Addition	Arithmetic
-	Subtraction	Arithmetic
/	Division	Arithmetic
<	Less than	Logical
<=	Less than or equal	Logical
<>	Not equal	Logical
=	Equals	Logical
>	Greater than	Logical
>=	Greater than or equal	Logical
abs	Absolute value	Arithmetic
acos	Inverse (arc) cosine in radians	Transcendental
and	Boolean AND	Logical
append_offset	Change time and date by a given amount	Timestamp
apply_offset	Change time and date by a given amount	Timestamp
asin	Inverse (arc) sine in radians	Transcendental
atan	Inverse (arc) tangent in radians	Transcendental
ceil	Round to next-highest integer	Arithmetic
cos	Cosine (input in radians)	Transcendental
exp	Exponential	Transcendental
first	Start of string	Strings
floor	Round to next-lowest integer	Arithmetic
get_offset	Returns time offset in seconds	Timestamp
high	String information	Strings
iif	Inline IF	Logical
is_nan	Returns TRUE is attribute value is NaN	Logical
is_null	Returns TRUE is attribute value is null	Logical
last	End of string	String
length	Get string length	String
log	Base-e logarithm	Transcendental
log10	Base-10 logarithm	Transcendental
low	String query	String
instanceid	Return instance id	Troubleshooting

Function Name	**Description**	**Category**
not	Boolean NOT	Logical
now	Current array version	Timestamp
or	Boolean OR	Logical
pow	Raise to a power	Arithmetic
random	Random number	Arithmetic
regex	Search for regular expression	Strings
sin	Sine (input in radians)	Transcendental
sqrt	Square root	Arithmetic
strchar	Convert string to char	Datatype conversion
strftime	Convert string to datetime	Datatype conversion
strip_offset	disregards OFFSET and returns result as a DATETIME	Timestamp
strlen	Maximum string length	Strings
substr	Select substring	Strings
tan	Tangent (input in radians)	Transcendental
togmt	Switch to GMT from current time zone setting	Timestamp
tznow	Set time zone	Timestamp

Chapter 12. SciDB Data Type Reference

SciDB supports the following data types.

Data Type	Description
binary	Machine-readable binary file
bool	Boolean TRUE (1) or FALSE (0)
char	Single-character
datetime	Date and time
datetimetz	Timezone
double	Double-precision decimal
float	Floating-point number
int8	Signed 8-bit integer
int16	Signed 16-bit integer
int32	Signed 32-bit integer
int64	Signed 64-bit integer
string	Character string
uint8	Unsigned 8-bit integer
uint16	Unsigned 16-bit integer
uint32	Unsigned 32-bit integer
uint64	Unsigned 64-bit integer
void	Return nothing

Chapter 13. SciDB Operator Reference

This reference guide lists the operators available in SciDB.

Name

analyze — Analyze load file for chunk size

Synopsis

```
SELECT * FROM analyze(array[, attribute1, attribute2, ...])
```

Summary

The analyze operator helps you decide how to set chunk size when you are creating a SciDB array. The analyze() operator takes as input a source array and a list of attributes in that source array. The operator computes the range of values (the maximum and minimum values), population count, and an estimate of the number of distinct values in the attribute (or combination of attributes).

Example

This example runs analyze on a 2-attribute, 1-dimensional array. The example uses the file doc/user/examples/num_data.scidb, shown here:

```
{0}[
(1.48306e+09,1),
(5.80814e+08,1),
(1.51079e+09,1),
(1.16154e+09,1),
(1.42655e+09,1),
(1.06341e+09,1),
(4.9253e+08,1),
(5.6065e+08,1),
(1.60886e+08,2),
(1.37844e+09,1),
(4.08495e+08,1),
(5.65393e+07,1),
(1.47646e+09,1),
(9.52609e+08,1),
(1.8548e+09,1),
(1.42396e+09,1),
(1.75107e+09,1),
(1.52007e+09,1),
(5.4882e+08,1),
(7.28928e+08,1)
]
```

1. Create an array analyze_array with 1 unbounded dimension:

   ```
   AQL% CREATE ARRAY analyze_array
   <val1:double,val2:double> [line=0:*,10,0];
   ```

2. Load the file num_data.scidb into analyze_array:

   ```
   AQL% LOAD analyze_array
   FROM 'path/doc/user/examples/num_data.scidb';
   ```

3. Analyze the array for chunk sizes:

```
analyze(analyze_array);
```

This query returns:

```
[("val","5.65393e+07","1.8548e+09",20,20),("val2","1","2",2,20)]
```

The output array contains one attribute for every attribute in the input. Each attribute of the output contains the attribute name, maximum value, minimum value, number of distinct elements, and total number of elements.

Name

apply — Apply expression to compute new attribute values

Synopsis

```
SELECT * FROM apply(array,new_attribute1,expression1
[,new_attribute2,expression2]);
```

```
store(apply(array,new_attribute1,expression1[,new_attribute2,expression2]),target_
```

Summary

Use the apply operator to compute new values from attributes and indexes of input arrays. The value(s) computed in the apply are appended to the attributes in the input array.

Example

This example computes new attributes for an existing array.

1. Create an array called distance with an attribute called miles:

   ```
   CREATE ARRAY distance <miles:double> [i=0:9,10,0];
   ```

2. Store values of 100–1000 into the array:

   ```
   store(build(distance,i+100.0),distance);
   ```

3. Apply the expression 1.6 * miles to distance and name the result kilometers:

   ```
   apply(distance,kilometers,1.6*miles);
   ```

   This query returns:

   ```
   [(100,160),
   (200,320),
   (300,480),
   (400,640),
   (500,800),
   (600,960),
   (700,1120),
   (800,1280),
   (900,1440),
   (1000,1600)]
   ```

Name

attribute_rename — Rename an array attribute

Synopsis

```
SELECT * FROM attribute_rename(array,old_attribute,new_attribute);
```

Summary

Changes an attribute name in an array.

Example

1. Create an array called array1 with an attribute called val:

   ```
   CREATE ARRAY array1 <val:double>[i];
   ```

2. Rename val to val2:

   ```
   attribute_rename(array1,val,val2);
   ```

Name

attributes — List array attributes

Synopsis

```
SELECT * FROM attributes(array);
```

Summary

The attributes operator lists all the attributes of an array. The output returns the attribute name, the attribute data type, and a Boolean flag representing whether or not the attribute can be null.

Name

avg — Average (mean) value

Synopsis

```
SELECT * FROM avg(array,attribute[,dimension1,dimension2,...]);
```

Summary

The avg operator finds the average value of an array attribute.

Note

The avg operator provides the same functionality as the avg aggregate, but has a different syntax. See the avg aggregate reference page.

Example

This example finds the average value along the second dimension of a 4×4 matrix.

1. Create an array named avg_array:

   ```
   CREATE ARRAY avg_array<val:double>[i=0:3,4,0,j=0:3,4,0];
   ```

2. Store values of 0–15 in avg_array:

   ```
   store(build(avg_array,i*4+j),avg_array);
   ```

   ```
   [
   [(0),(1),(2),(3)],
   [(4),(5),(6),(7)],
   [(8),(9),(10),(11)],
   [(12),(13),(14),(15)]
   ]
   ```

3. Find the average value along the dimension j:

   ```
   avg(avg_array,val,j);
   ```

   This query outputs:

   ```
   [(1.5),(5.5),(9.5),(13.5)]
   ```

Name

bernoulli — Select random array cells

Synopsis

```
SELECT * FROM bernoulli(array,probability[, seed]);
```

Summary

The bernoulli operator evaluates each cell by generating a random number and seeing if it lies in the range (0, probability). If it does, the cell is included.

Example

This example select cells at random from a 4×4 matrix, and uses a seed value to select the same cells in successive trials.

1. Create an array called bernoulli_array:

   ```
   CREATE ARRAY bernoulli_array<val:double>[i=0:3,4,0,j=0:3,4,0];
   ```

2. Store values of 0–15 in bernoulli_array:

   ```
   store(build(bernoulli_array,i*4+j),bernoulli_array);
   ```

   ```
   [
   [(0),(1),(2),(3)],
   [(4),(5),(6),(7)],
   [(8),(9),(10),(11)],
   [(12),(13),(14),(15)]
   ]
   ```

3. Select cells at random with a probability of .5 that a cell will be included. Each successive call to bernoulli will return different results.

   ```
   AFL% bernoulli(bernoulli_array,.5);
   ```

   ```
   [
   [(),(1),(),(3)],
   [(4),(),(),()],
   [(),(9),(),(11)],
   [(12),(),(14),(15)]
   ]
   ```

   ```
   bernoulli(bernoulli_array,.5);
   ```

   ```
   [
   [(),(1),(),(3)],
   [(),(5),(6),()],
   [(),(9),(),(11)],
   [(),(13),(14),()]]
   ```

4. To reproduce earlier results, use a seed value. Seeds must be an integer on the interval [0, INT_MAX].

```
bernoulli(bernoulli_array,.5,1);
```

```
[
[(),(),(2),()],
[(),(),(6),(7)],
[(8),(9),(),(11)],
[(12),(),(),()]
]
```

```
AFL% bernoulli(bernoulli_array,.5,1);
```

```
[
[(),(),(2),()],
[(),(),(6),(7)],
[(8),(9),(),(11)],
[(12),(),(),()]
]
```

Name

between — Select array data from specified region

Synopsis

```
SELECT * FROM between(array,low_coord1,low_coord2,...,high_coord1,high_coord2);
```

Summary

The between operator accepts an input array and a set of coordinates specifying a region within the array. The number of coordinate pairs in the input must be equal to the number of dimensions in the array. The output is an array of the same shape as input, where all cells outside of the given region are marked empty.

Example

This example selects 4 elements from a 16-element array.

1. Create a 4×4 array called between_array:

   ```
   CREATE ARRAY between_array <val:double>[i=0:3,4,0,j=0:3,4,0];
   ```

2.
   ```
   store(build(between_array,i*4+j),between_array);
   ```

   ```
   [
   [(0),(1),(2),(3)],
   [(4),(5),(6),(7)],
   [(8),(9),(10),(11)],
   [(12),(13),(14),(15)]
   ]
   ```

3. Select all values from the last two rows and last two columns from between_array:

   ```
   between(between_array,2,2,3,3);
   ```

   This query outputs:

   ```
   [
   [(),(),(),()],
   [(),(),(),()],
   [(),(),(10),(11)],
   [(),(),(14),(15)]
   ]
   ```

Name

build — Assign values to array attribute

Synopsis

```
SELECT * INTO target_array FROM build(source_array,expression);

store(build(source_array,expression);
```

Summary

The build operator proceeds through source_array, cell by cell, using the value of expression to compute the value of each cell. The expression argument can be any combination of SciDB functions applied to scalars or SciDB array attributes.

Example

Create an array of all ones:

```
build(<val:double>[i=0:3,4,0,j=0:3,4,0],1);
```

Create an identity matrix:

```
build(<val:double>[i=0:3,4,0,j=0:3,4,0],iif(i=j,1,0));
```

Build an array of monotonically increasing values:

```
build(<val:double>[i=0:3,4,0,j=0:3,4,0],i*4+j);
```

To store the result from a build operator, create an array and use the store operator with the build operator.

```
CREATE ARRAY identity_matrix <val:double>[i=0:3,4,0,j=0:3,4,0];
store(build(identity_matrix,iif(i=j,1,0)),identity_matrix);
```

Limitations

- The build operator can only take arrays with one attribute.
- The build operator can only take arrays with bounded dimensions.

Name

build_sparse — Assign values to attributes of a sparse array

Synopsis

```
SELECT * INTO target_array FROM build_sparse(source_array,expression,boolean_expre

store(build_sparse(source_array,expression,boolean_expression));
```

Summary

The build_sparse operator takes as input an array or anonymous schema, an expression that defines a scalar value, and an expression that defines a Boolean value. The output of build_sparse contains an array with the same schema as the input array or anonymous schema, the value specified by *expression* wherever *boolean_expression* evaluates to true, and empty cells wherever *boolean_expression* evaluates to false.

Example

Build a sparse-formatted identity matrix where the cells that would be occupied by 0 are empty:

```
build_sparse(<val:double>[i=0:3,4,0,j=0:3,4,0],1,i=j);
```

This query outputs:

```
[[{0,0}(1),{1,1}(1),{2,2}(1),{3,3}(1)]]
```

Name

cancel — Cancel a query

Synopsis

```
cancel(query_id);
```

This operator is designed for internal use.

Summary

Cancel a currently running query by query id.

The query id can be obtained from the SciDB log or via the list() command. SciDB maintains query context information for each completed and in-progress query in the server. If the user issues a "ctrl-C" or abort from the client, the query is cancelled and its context is removed from the server.

Name

cast — Change attribute and dimension names

Synopsis

```
SELECT * INTO target_array FROM cast(source_array, schema);

store(cast(source_array,schema),target_array);
```

Summary

The cast operator allows renaming an array or any of its attributes and dimensions. A single cast invocation can be used to rename multiple items at once (one or more attribute names and/or one or more dimension names). The input array and template arrays should have the same numbers and types of attributes and the same numbers and types of dimension.

Example

This example changes the name of an array attribute and an array dimension. The arrays must be compatible; that is, they must have the same number of dimensions and attributes, and the attributes and dimensions must be of the same type.

1. Create an array called source with an attribute called val and a dimension called i:

   ```
   CREATE ARRAY source <val:double>[i=0:9,10,0];
   ```

2. Use an anonymous schema to change the attribute name to num_val and the dimension name to x. Store the result in an array called target:

   ```
   store(cast(source, <num_val:double>[x=0:9,10,0]),target);
   ```

   This is useful when you are joining arrays and want to avoid naming conflicts. For example, doing a cross_join on source and target will create an array with two attributes, val and num_val, and two dimensions, i and x:

   ```
   store(cross_join(source,target),new_array);
   show(new_array);
   ```

   ```
   [("new_array<val:double,num_val:double> [i=0:9,10,0,x=0:9,10,0]")]
   ```

Name

concat — Concatenate two arrays

Synopsis

```
SELECT * INTO target_array FROM concat(left_array,right_array);

store(concat(left_array,right_array),target_array);
```

Summary

The concat operator concatenates two arrays with the name number of dimensions. Concatenation is performed by the left-most dimension. All other dimensions of the input arrays must match. The left-most dimension of both arrays must have a fixed size (not unbounded) and same chunk size and overlap. Both inputs must have the same attributes.

Example

This example concatenates a 4×3 array and a 1×3 array.

1. Create a 4×3 array left_array containing value 1 in all cells:

   ```
   create array left_array <val:double>[i=0:3,1,0,j=0:3,1,0];
   store(build(left_array,1),left_array);
   ```

2. Create a 1×3 array right_array containing value 0 in all cells:

   ```
   create array right_array <val:double>[i=0:1,1,0,j=0:2,1,0];
   store(build(right_array,0),right_array);
   ```

3. Concatentate left_array and right_array and store the result in concat_array:

   ```
   store(concat(left_array,right_array),concat_array);
   ```

   This produces an array concat_array with contents and schema as follows:

   ```
   show(concat_array);scan(concat_array);
   ```

   ```
   show(concat_array);scan(concat_array);
   [("concat_array<val:double> [i=0:5,1,0,j=0:2,1,0]")]
   [[(1)]];[[(1)]];[[(1)]];[[(1)]];[[(1)]];[[(1)]];
   [[(1)]];[[(1)]];[[(1)]];[[(1)]];[[(1)]];[[(1)]];
   [[(0)]];[[(0)]];[[(0)]];[[(0)]];[[(0)]];[[(0)]]
   ```

Name

count — Count nonempty cells

Synopsis

```
SELECT * FROM count(array);
```

Summary

The count operator counts nonempty cells of the input array. When dimensions are provided they are used to do a group-by and a count per resulting group is returned.

Note

The count operator provides the same functionality as the count aggregate. See the count aggregate page.

Example

This example finds the average value along the second dimension of a 4×4 array where some cells are empty.

1. Create an array named source_array:

   ```
   CREATE ARRAY source_array<val:double>[i=0:3,4,0,j=0:3,4,0];
   ```

2. Store values of 0–15 in source_array:

   ```
   store(build(source_array,i*4+j),source_array);
   ```

   ```
   [
   [(0),(1),(2),(3)],
   [(4),(5),(6),(7)],
   [(8),(9),(10),(11)],
   [(12),(13),(14),(15)]
   ]
   ```

3. Use between to create some empty cells in source_array and store the result in count_array:

   ```
   store(between(source_array,1,1,1,2),count_array);
   ```

   ```
   [
   [(),(),(),()],
   [(),(5),(6),()],
   [(),(),(),()],
   [(),(),(),()]
   ]
   ```

4. Find the count of nonempty element in count_array:

   ```
   count(count_array);
   ```

   This query outputs:

```
[(2)]
```

5. Count the nonempty elements along the dimensions of count_array:

```
count(count_array,i);
```

```
[(0),(2),(0),(0)]
```

```
count(count_array,j);
```

```
[(0),(1),(1),(0)]
```

Name

cross — Cross-product join

Synopsis

```
SELECT * INTO m3xtarget_array FROM cross(left_array,right_array);
```

Summary

Calculates the full cross product join of two arrays, say A (m-dimensional array) and B (n-dimensional array) such that the result is an m+n dimensional array in which each cell is computed as the concatenation of the attribute lists from corresponding cells in arrays A and B. For example, consider a 2-dimensional array A with dimensions i, j, and a 1-dimensional array B with dimension k. The cell at coordinate position {i, j, k} of the output is computed as the concatenation of cells {i, j} of A with cell at coordinate {k} of B.

Example

This example returns the cross-join of a 3×3 array with a vector of length 2.

1. Create a 3×3 array m3x3:

   ```
   CREATE ARRAY m3x3<val:double>[i=0:2,3,0,j=0:2,3,0];
   ```

2. Put values of 0–8 into m3x3:

   ```
   store(build(m3x3,i*3+j),m3x3);
   ```

3. Create a vector of length 2 containing values 101 and 102:

   ```
   store(build(<val:double>[i=0:1,1,0],i+101),vector);
   ```

4. Find the cross of m3x3 and vector:

   ```
   store(cross(m3x3,vector),cross_array);
   ```

   This query returns:

   ```
   [
   [[(0,101)],[(1,101)],[(2,101)]],
   [[(3,101)],[(4,101)],[(5,101)]],
   [[(6,101)],[(7,101)],[(8,101)]]];

   [[[(0,102)],[(1,102)],[(2,102)]],
   [[(3,102)],[(4,102)],[(5,102)]],
   [[(6,102)],[(7,102)],[(8,102)]]]
   ```

   The array cross_array has schema:

   ```
   show(cross_array);
   ```

   ```
   [("cross_array<val:double,val_2:double> [i=0:2,3,0,j=0:2,3,0,i_2=0:1,1,0]")]
   ```

Name

cross_join — Cross-product join with equality predicates

Synopsis

```
SELECT * INTO target_array FROM cross_join(left_array,right_array,left_dim1,right_

store(cross_join(left_array,right_array,left_dim1,right_dim_1,...),tagrget_array);
```

Summary

Calculates the cross product join of two arrays, say A (m-dimensional array) and B (n-dimensional array) with equality predicates applied to pairs of dimensions, one from each input. Predicates can only be computed along dimension pairs that are aligned in their type, size, and chunking.

Assume p such predicates in the cross_join, then the result is an m+n-p dimensional array in which each cell is computed by concatenating the attributes as follows:

For a 2-dimensional array A with dimensions i, j, and a 1-dimensional array B with dimension k, cross_join(A, B, j, k) results in a 2-dimensional array with coordinates {i, j} in which the cell at coordinate position {i, j} of the output is computed as the concatenation of cells {i, j} of A with cell at coordinate {k=j} of B.

Example

This example returns the cross-join of a 3×3 array with a vector of length 3.

1. Create an array called left_array:

   ```
   create array left_array<val: double>[i=0:2,3,0, j=0:2,3,0];
   ```

2. Store values of 0–8 into left array:

   ```
   store(build(left_array,i*3+j),left_array);
   ```

3. Create an array called right_array:

   ```
   create array right_array<val: double>[k=1:3,3,0];
   ```

4. Store values of 101–103 into right_array:

   ```
   store(build(right_array,k+101),right_array);
   ```

5. Perform a cross-join on left_array and right_array along dimension j of left_array:

   ```
   cross_join(left_array,right_array,j,k);
   ```

   This query outputs:

   ```
   [
   [(0,101),(1,102),(2,103)],
   [(3,101),(4,102),(5,103)],
   [(6,101),(7,102),(8,103)]
   ]
   ```

Name

deldim — Reduce array dimensionality

Synopsis

```
SELECT * FROM deldim(array);
```

Summary

The deldim operator deletes the left-most dimension from the array. Deleted dimension must have size = 1. See the adddim operator reference page for an example.

Name

dimensions — List array dimensions

Synopsis

```
SELECT * FROM dimensions(array);
```

Summary

The argument to the dimensions operator is the name of the array. It returns an array with the following attributes: dimension-name, dimension start-index, dimension-length, chunk size, chunk overlap, low-boundary-index, high-boundary-index, datatype.

Example

This example creates an array with one unbounded dimension and one string-type dimension:

```
CREATE ARRAY unbound_string_dim
<val:double>[i=0:*,10,0,j(string)=10,10,0];
dimensions(unbound_string_dim);
```

This code outputs:

```
[("i",0,4611686018427387903,10,0,4611686018427387903,
-4611686018427387903,"int64"),
("j",0,10,10,0,4611686018427387903,-4611686018427387903,
"string")]
```

Name

diskinfo — Internal debugging: Check disk capacity

Synopsis

```
diskinfo()
```

This operator is designed for internal use.

Summary

Get information about storage space. Returns an array with the following attributes:

- used
- available
- clusterSize
- nFreeClusters
- • nSegments

Name

echo — Print string

Synopsis

```
echo(string)
```

This operator is designed for internal use.

Summary

Accepts a string and returns a single-element array containing the string.

Name

explain_logical, explain_physical — Show query plan

Synopsis

```
explain_logical( query: string, language: string )
explain_physical( query: string, language: string )
```

This operator is designed for internal use.

Summary

The operators explain_logical and explain_physical can be used to emit a human-readable plan string for a particular query without running the query itself. SciDB first constructs a logical plan, optimizes it and then translates it into a physical plan.

Name

filter — Select subset of data by boolean expression

Synopsis

```
SELECT * FROM filter(array,expression);
```

Summary

The filter operator filters out data in the array based on an expression over the attribute and dimension values. The filter operator returns an array the with the same schema as the input array but marks all cells in the input that do not satisfy the predicate expression 'empty'.

Example

This example filters an array to remove outlying values.

1. Create an array m4x4:

   ```
   CREATE ARRAY m4x4<val:double>[i=0:3,4,0,j=0:3,4,0];
   ```

2. Put values between 0 and 15 into the nondiagonal elements of m4x4 and values greater than 100 into the diagonal elements:

   ```
   store(build(m4x4,iif(i=j,100+i,i*4+j)),m4x4);
   ```

   ```
   [
   [(100),(1),(2),(3)],
   [(4),(101),(6),(7)],
   [(8),(9),(102),(11)],
   [(12),(13),(14),(103)]
   ]
   ```

3. Filter all values of 100 or greater out of m4x4:

   ```
   filter(m4x4,val<100);
   ```

   This query outputs:

   ```
   [
   [(),(1),(2),(3)],
   [(4),(),(6),(7)],
   [(8),(9),(),(11)],
   [(12),(13),(14),()]
   ]
   ```

Name

help — Operator signature

Synopsis

```
SELECT * FROM help(operator_name);
```

Summary

Accepts an operator name and returns an array containing a human-readable signature for that operator.

Example

This example returns the signature of the multiply operator.

```
help('multiply');
```

Name

input — Read a system file

Synopsis

```
SELECT * INTO target_array FROM input(source_array,filename,[,instance_id]);

store(input(target_array,filename),target_array[,instance_id]);
```

Summary

Input works exactly the same way as load, except it does NOT store the data unless the INTO clause or the AFL store operator is present. The instance_id argument allows you to select which SciDB instance you want to input into. To see a list of SciDB instances running on your system, type scidb.py status hostname athte Unix command-line.

Example

This example reads a csv file from the examples directory.

```
input(m4x4,'path/trunk/doc/user/examples/m4x4_missing.txt);
```

Name

inverse — Matrix inverse

Synopsis

```
SELECT * FROM inverse(array);
```

Summary

The inverse operator produces the matrix inverse of a square matrix. The input matrix must be invertible, i.e., the determinant of the matrix must be nonzero.

Example

This example find the matrix inverse of a 3×3 matrix.

1. Create a matrix m3x3:

   ```
   CREATE ARRAY <val:double>[i=0:2,3,0,j=0:2,3,0];
   ```

2. Put values of 1 and 2 into m3x3 to represent a nonsingular matrix:

   ```
   store(build(m3x3,iif(i=j,1,2)),m3x3);
   ```

   This query outputs:

   ```
   [
   [(1),(2),(2)],
   [(2),(1),(2)],
   [(2),(2),(1)]
   ]
   ```

3.
   ```
   inverse(m3x3);
   ```

   This query outputs:

   ```
   [
   [(-0.6),(0.4),(0.4)],
   [(0.4),(-0.6),(0.4)],
   [(0.4),(0.4),(-0.6)]
   ]
   ```

Name

join — Join two arrays

Synopsis

```
SELECT * INTO target_array FROM join(left_array,right_array);

store(join(left_array,right_array),target_array)
```

Summary

Join combines the attributes of two input arrays at matching dimension values. The join result has the same dimension names as the first input. The left and right arrays must have the same shape. If a cell in either the left or right array is empty, the corresponding cell in the result is also empty.

Example

This example concatenates two 3×3 arrays.

1. Create a 3×3 array left_array containing value 1 in all cells:

   ```
   create array left_array <val:double>[i=0:2,3,0,j=0:2,3,0];
   store(build(left_array,1),left_array);
   ```

2. Create a 3×3 array right_array containing value 0 in all cells:

   ```
   create array right_array <val:double>[i=0:2,3,0,j=0:2,3,0];
   store(build(right_array,0),right_array);
   ```

3. Join left_array and right_array:

   ```
   join(left_array,right_array);
   ```

   This produces an array concat_array with contents and schema as follows:

   ```
   show(concat_array);scan(concat_array);
   ```

   ```
   show(concat_array);scan(concat_array);
   [("concat_array<val:double> [i=0:5,1,0,j=0:2,1,0]")]
   [[(1)]];[[(1)]];[[(1)]];[[(1)]];[[(1)]];[[(1)]];
   [[(1)]];[[(1)]];[[(1)]];[[(1)]];[[(1)]];[[(1)]];
   [[(0)]];[[(0)]];[[(0)]];[[(0)]];[[(0)]];[[(0)]]
   ```

Name

list — List contents of SciDB namspace

Synopsis

```
SELECT * FROM list(element)
```

Summary

The list operator allows you to get a list of elements in the current SciDB instance. The input is one of the following strings:

aggregates	Show all operators that take as input a SciDB array and return a scalar.
arrays	Show all functions. Each function will be listed with its available dataypes and the library in functions which it resides.
functions	Show all libraries that are loaded in the current SciDB instance.
instances	Show all SciDB instances. Each instance will be listed with its port, id number, and time-and-date stamps for when it came online.
libraries	Show all libraries that are loaded in the current SciDB session.
operators	Show all operators and the libraries in which they reside.
types	Show all the dataypes the SciDB supports.
queries	Show all active queries. Each active query will have an id, a time and date when it was queries initiated, an error code, whether it generated any errors, and a status (boolean flag where TRUE means that the query is idle).

Name

load_library — Load a plugin

Synopsis

```
load_library(library_name);
```

Summary

Load a SciDB plugin. The act of loading a plugin shared library first registers the library in the SciDB system catalogs. Then it opens and examines the shared library to store its contents with SciDB's internal extension management subsystem. Shared library module which are registered with the SciDB instance will be loaded at system start time.

Example

```
load_library('librational')
```

Name

lookup — Select array cells by dimension index

Synopsis

```
SELECT * FROM lookup(pattern_array,source_array);
```

Summary

Lookup maps elements from the second array using the attributes of the first array as coordinates into the second array. The result array has the same shape as first array and the same attributes as second array.

Example

This example selects a row from a 2-dimensional array.

1. Create an vector of ones called indices1:

   ```
   store(build(<val1:double>[i=0:3,4,0],1),indices1);
   ```

   ```
   [(1),(1),(1),(1)]
   ```

2. Create a vector with values between 0 and 3 called indices2:

   ```
   store(build(<val1:double>[i=0:3,4,0],i),indices2);
   ```

   ```
   [(0),(1),(2),(3)]
   ```

3. Join indices1 and indices2 into a two-attribute array called pattern_array:

   ```
   store(join(indices1,indices2),pattern_array);
   ```

   ```
   [(1,0),(1,1),(1,2),(1,3)]
   ```

4. Create a 2-dimensional array called source_array with values between 100 and 115:

   ```
   store(build(<val:double>[i=0:3,4,0,j=0:3,4,0],i*4+j+100),source_array);
   ```

   ```
   [
   [(100),(101),(102),(103)],
   [(104),(105),(106),(107)],
   [(108),(109),(110),(111)],
   [(112),(113),(114),(115)]
   ]
   ```

5. Use lookup to use the dimension coordinates array pattern_array to return the second row of source_array:

   ```
   lookup(pattern_array,source_array);
   ```

   This query outputs:

   ```
   [(104),(105),(106),(107)]
   ```

Name

max — Select maximum value

Synopsis

```
SELECT * FROM max(array[,attribute][,dimension1,dimension2,...])
```

Summary

The max operator calculate maximum of the specified attribute in the array. Result is an array with single element containing maximum of specified attribute.

Note

The max operator provides the same functionality as the max aggregate. See the max aggregate reference page for more information.

Example

This example find the maximum value of each row of a 2-dimensional array.

1. Create a 1-attribute, 2-dimensional array called m3x3:

   ```
   CREATE ARRAY m3x3 <val:double>[i=0:2,3,0,j=0:2,3,0];
   ```

2. Store values of 0–8 in m3x3:

   ```
   store(build(m3x3,i*3+j),m3x3);
   ```

   ```
   [
   [(0),(1),(2)],
   [(3),(4),(5)],
   [(6),(7),(8)]
   ]
   ```

3. Select the maximum value of each row of m3x3:

   ```
   max(m3x3,val,i);
   ```

   This query returns:

   ```
   [(2),(5),(8)]
   ```

Name

merge — Merge two arrays

Synopsis

```
SELECT * INTO target_array FROM merge(left_array,right_array);
```

Summary

Merge combines elements from the input array the following way: for each cell in the two inputs, if the cell of first (left) array is non-empty, then the attributes from that cell are selected and placed in the output. If the cell in the first array is marked as empty, then the attributes of the corresponding cell in the second array are taken. If the cell is empty in both input arrays, the output's cell is set to empty.

The two input arrays should have the same shape as one another: that is, the same attribute list and dimensions.

Example

This example merges two sparse arrays.

1. Create a sparse array left_array containing value 1 in the first row:

   ```
   store(build_sparse(<val:double>[i=0:2,3,0,j=0:2,3,0],1,i=0),left_array);
   ```

   This query outputs:

   ```
   [[{0,0}(1),{0,1}(1),{0,2}(1)]]
   ```

2. Create a sparse identity matrix called right_array

   ```
   store(build_sparse(<val:double>[i=0:2,3,0,j=0:2,3,0],1,i=j),right_array);
   ```

   This query outputs:

   ```
   [[{0,0}(1),{1,1}(1),{2,2}(1)]]
   ```

3. Merge left_array and right_array:

   ```
   merge(left_array,right_array);
   ```

   This query outputs:

   ```
   [[{0,0}(1),{0,1}(1),{0,2}(1),{1,1}(1),{2,2}(1)]]
   ```

Name

min — Select minimum value

Synopsis

```
SELECT * FROM min(array,attribute[,dimension_1,dimension_2,...]);
```

Summary

The min operator selects the minimum value from an array attribute.

Note

The min operator provides the same functionality as the min aggregate. See the min aggregate reference page for more information.

Example

This example finds the minimum value of each row of a 2-dimensional array.

1. Create a 1-attribute, 2-dimensional array called m3x3:

   ```
   CREATE ARRAY m3x3 <val:double>[i=0:2,3,0,j=0:2,3,0];
   ```

2. Store values of 0–8 in m3x3:

   ```
   store(build(m3x3,i*3+j),m3x3);
   ```

   ```
   [
   [(0),(1),(2)],
   [(3),(4),(5)],
   [(6),(7),(8)]
   ]
   ```

3. Select the minimum value of each row of m3x3:

   ```
   max(m3x3,val,i);
   ```

   This query returns:

   ```
   [(0),(3),(6)]
   ```

Name

multiply — Matrix multiplication

Synopsis

```
SELECT * FROM multiply(left_array,right_array);
```

Summary

The multiply operator performs matrix multiplication on two input matrices and returns a result matrix.

Both inputs must be compatible for the multiply operation, and both must have a single attribute. To be compatible, two matrices must have the same size of 'inner' dimension and same chunk size along that dimension.

Example

This example multiplies a 3×2 array and a 2×3 array.

1. Create a 3×2 array lhs:

   ```
   store(build(<val:double>[i=0:2,3,0,j=0:1,2,0],(i+1)*3+j),lhs);
   ```

   This query outputs:

   ```
   [
   [(3),(4)],
   [(6),(7)],
   [(9),(10)]
   ]
   ```

2. Create a 2×3 array rhs:

   ```
   store(build(<val:double>[i=0:1,2,0,j=0:2,3,0],(i+1)*3-j),rhs);
   ```

   ```
   [
   [(3),(2),(1)],
   [(6),(5),(4)]
   ]
   ```

3. Multiply lhs and rhs.

   ```
   multiply(lhs,rhs)
   ```

   This query returns:

   ```
   [
   [(33),(26),(19)],
   [(60),(47),(34)],
   [(87),(68),(49)]
   ]
   ```

Name

normalize — Divide each element of a vector by the square root of the sum of squares of the elements

Synopsis

```
SELECT * FROM normalize(array,attribute);
```

Summary

The normalize operator scales the values of a vector.

Example

Scale a vector whose values are between 1 and 10.

```
store(build(<val:double>[i=0:9,10,0],(i+1)),unscaled);
[(1),(2),(3),(4),(5),(6),(7),(8),(9),(10)]
normalize(unscaled);
[(0.0509647),(0.101929),(0.152894),(0.203859),(0.254824),(0.305788),(0.356753),(0.
```

Limitations

The normalize operator can only take 1-dimensional arrays.

Name

project — Select array attributes

Synopsis

```
SELECT * INTO target_array FROM project(source_array, attribute1, attribute2,...);

store(project(source_array,attribute1,attribute2,...),target_array);
```

Summary

Project the input array on the specified attributes, in the specified order. Attributes that are not specified are excluded from the output.

Example

This example takes an array with 3 attributes and returns an array with 2 attributes.

1. Create an array source_array:

   ```
   store(build(<val1:double>[i=0:4,5,0],1),source_array);
   ```

   This query outputs:

   ```
   [(1),(1),(1),(1),(1)]
   ```

2. Create an attribute val2 and store val1 and val2 in the array:

   ```
   store(apply(source_array,val2,i+1),two_attr);
   ```

   ```
   [(1,1),(1,2),(1,3),(1,4),(1,5)]
   ```

3. Create an attribute called val3 and store val1, val2, and val3 in an array three_attr:

   ```
   store(apply(two_attr,val3,sin(val2/1.0)),three_attr);
   ```

   ```
   [(1,1,0.841471),(1,2,0.909297),(1,3,0.14112),(1,4,-0.756802),(1,5,-0.958924)]
   ```

4. Project attribute val3 and val2:

   ```
   project(three_attr,val3,val2);
   ```

   This query outputs:

   ```
   [(0.841471,1),(0.909297,2),(0.14112,3),(-0.756802,4),(-0.958924,5)]
   ```

Name

redimension — Change attributes to dimensions

Synopsis

```
AFL% redimension(source_array,target_array)
```

Summary

The redimension operator changes attributes to dimensions. The input and target arrays must have compatible schemas, and both commands determine the list of transformations (attribute to dimension) by matching names in the attribute and dimension lists of the two arrays.

Example

This example redimensions a 2-attribute, 1-dimensional array into a 2-dimensional, 1-attribute array. This example uses the data set expo_example.txt, shown here:

```
s,p,val
"device-0","probe-0",0.01
"device-1","probe-0",2.04
"device-2","probe-0",6.09
"device-3","probe-0",12.16
"device-4","probe-0",20.25
"device-0","probe-1",30.36
"device-1","probe-1",42.49
"device-2","probe-1",56.64
"device-3","probe-1",72.81
"device-4","probe-1",91
"device-0","probe-2",111.21
"device-1","probe-2",133.44
"device-2","probe-2",157.69
"device-3","probe-2",183.96
"device-4","probe-2",212.25
"device-0","probe-3",242.56
"device-1","probe-3",274.89
"device-2","probe-3",309.24
"device-3","probe-3",345.61
"device-4","probe-3",384
"device-0","probe-4",424.41
"device-1","probe-4",466.84
"device-2","probe-4",511.29
"device-3","probe-4",557.76
"device-4","probe-4",606.25
```

1. Create an array named expo, with one cell for every row in expo_example.txt

   ```
   CREATE ARRAY expo
   <s:string,p:string,val:double>
   [i=1:25,5,0]
   ```

2. Convert the file expo_example.txt to SciDB format. You will need to exit your iquery session or do this in a new terminal window because the csv2scidb tool is run at the command line.

```
csv2scidb -p SSN -s N < expo_example.txt > expo_example.scidb
```

3. Load the data expo_example.txt into expo:

   ```
   LOAD expo FROM '/doc/examples/expo_example.txt';
   ```

4. Create an array with a noninteger dimension to be the redimension target:

   ```
   CREATE ARRAY Dsp
   <val:double>
   [s(string)=5,5,0, p(string)=5,5,0];
   ```

5. Redimension expo into Dsp:

   ```
   redimension(expo, Dsp);
   ```

   This query returns:

   ```
   [
   [(0.01),(30.36),(111.21),(242.56),(424.41)],
   [(2.04),(42.49),(133.44),(274.89),(466.84)],
   [(6.09),(56.64),(157.69),(309.24),(511.29)],
   [(12.16),(72.81),(183.96),(345.61),(557.76)],
   [(20.25),(91),(212.25),(384),(606.25)]
   ]
   ```

Name

redimension_store — Transform attributes to dimensions

Synopsis

```
AFL% redimension_store(source_array,target_array);
```

Summary

redimension_store converts array attributes to dimensions. The redimension_store operator updates the target_array and creates additional mapping arrays if necessary.

You can redimension the array and apply aggregates to duplicate cells.

The input and target arrays must have compatible schemas, and both commands determine the list of transformations (attribute to dimension) by matching names in the attribute and dimension lists of the two arrays.

Example

This example redimensions a 2-attribute, 1-dimensional array into a 2-dimensional, 1-attribute array. This example uses the data set expo_example.txt, shown here:

```
s,p,val
"device-0","probe-0",0.01
"device-1","probe-0",2.04
"device-2","probe-0",6.09
"device-3","probe-0",12.16
"device-4","probe-0",20.25
"device-0","probe-1",30.36
"device-1","probe-1",42.49
"device-2","probe-1",56.64
"device-3","probe-1",72.81
"device-4","probe-1",91
"device-0","probe-2",111.21
"device-1","probe-2",133.44
"device-2","probe-2",157.69
"device-3","probe-2",183.96
"device-4","probe-2",212.25
"device-0","probe-3",242.56
"device-1","probe-3",274.89
"device-2","probe-3",309.24
"device-3","probe-3",345.61
"device-4","probe-3",384
"device-0","probe-4",424.41
"device-1","probe-4",466.84
"device-2","probe-4",511.29
"device-3","probe-4",557.76
"device-4","probe-4",606.25
```

1. Create an array named expo, with one cell for every row in expo_example.txt

   ```
   CREATE ARRAY expo
   ```

```
<s:string,p:string,val:double>
[i=1:25,5,0]
```

2. Convert the file expo_example.txt to SciDB format. You will need to exit your iquery session or do this in a new terminal window because the csv2scidb tool is run at the command line.

   ```
   csv2scidb -p SSN -s N < expo_example.txt > expo_example.scidb
   ```

3. Load the data expo_example.txt into expo:

   ```
   LOAD expo FROM '/doc/examples/expo_example.txt';
   ```

4. Create an array with a noninteger dimension to be the redimension target:

   ```
   CREATE ARRAY Dsp
   <val:double>
   [s(string)=5,5,0, p(string)=5,5,0];
   ```

5. Redimension expo and store the result in Dsp:

   ```
   redimension_store(expo, Dsp);
   ```

   This query returns:

   ```
   [
   [(0.01),(30.36),(111.21),(242.56),(424.41)],
   [(2.04),(42.49),(133.44),(274.89),(466.84)],
   [(6.09),(56.64),(157.69),(309.24),(511.29)],
   [(12.16),(72.81),(183.96),(345.61),(557.76)],
   [(20.25),(91),(212.25),(384),(606.25)]
   ]
   ```

Name

reduce_distro — Reduce the distribution of a replicated array

Synopsis

```
AFL% reduce_distro( array, partitioning_schema: integer )
```

Summary

Internal only.

Name

regrid — Select nonoverlapping subarrays

Synopsis

```
SELECT * FROM regrid(array,grid_1, grid_2,...,grid_N,
aggregate_call_1 [, aggregate_call_2,...,aggregate_call_N])
```

Summary

The regrid operator partitions the cells in the input array into blocks, and for each block, apply a specific aggregate operation over the value(s) of some attribute in each block.

regrid does not allow grids to span array chunks and requires the chunk size to be a multiple of the grid size in each dimension.

Example

This example divides a 4×4 array into 4 equal partitions and calculates the average of each one. This process is known as *spatial averaging*.

1. Create an array m4x4:

   ```
   CREATE ARRAY m4x4 <val:double> [i=0:3,4,0,j=0:3,4,0];
   ```

2.
   ```
   store(build (m4x4, i*4+j), m4x4);
   ```

   ```
   [
   [(0),(1),(2),(3)],
   [(4),(5),(6),(7)],
   [(8),(9),(10),(11)],
   [(12),(13),(14),(15)]
   ]
   ```

3. Regrid m4x4 into four partitions and find the average of each partition.

   ```
   regrid(m4x4, 2,2, sum(val));
   ```

   This query outputs:

   ```
   [[(2.5),(4.5)],[(10.5),(12.5)]]
   ```

Name

remove — Remove an array from the SciDB namespace

Synopsis

```
AFL% remove(array);
```

Summary

The AFL remove operator works like the AQL DROP ARRAY statement.

Example

Create an array named source and then remove it:

```
store(build(<val:double>[i=0:9,10,0],1),source);
remove(source);
```

Name

rename — Change array name

Synopsis

```
AFL% rename(array,new_array)
```

Summary

The AFL rename operator work similarly to the AQL statement SELECT * INTO except that the old array name can be reused immediately with the rename operator. The rename operator is akin to using the Unix mv command, whereas SELECT * INTO is akin to the Unix cp command.

Example

Create an array named source and rename source to target.

```
store(build(<val:double>[i=0:9,10,0],1),source);
rename(source,target);
```

Name

repart — Change array chunk sizes

Synopsis

```
SELECT * FROM repart(array,target_array|array_schema)
```

Summary

The repart operator changes the partitioning (chunking) of the array. The target array must have the same attributes and dimensions, but chunk size may be different. Repart returns an array whose attributes are taken from the input array, with the dimensions of the target.

Example

This example repartitions a 4×4 array with chunk size 1 into an array with chunk size 2.

1. Create an array with chunk size of 1 called source:

   ```
   CREATE ARRAY source <val:double> [x=0:3,1,0,y=0:3,1,0];
   ```

2. Add values of 0–15 to source:

   ```
   store(build(source,x*3+y),source);
   ```

3. Repartition the array into 2-by-2 chunks and store the result in an array called target:

   ```
   store(repart(source, <values:double> [x=0:3,2,0, y=0:3,2,0]),target);
   ```

Name

reshape — Change dimension sizes and array shape

Synopsis

```
SELECT * FROM reshape(array,array|array_schema);
```

Summary

The reshape operator changes the shape of an array to the rank and dimensions of a given array or a given array schema. The the reshape command inputs must have the same number of total cells and cell attributes.

Example

This example reshapes a 4×4 array into a 2×8 array.

1. Create an array called m4x4:

   ```
   CREATE ARRAY m4X4 <val:double>[i=0:3,4,0,j=0:3,4,0];
   ```

2. Store values of 0–15 in m4x4:

   ```
   store(build(m4x4,i*4+j),m4x4);
   ```

   This query outputs:

   ```
   [
   [(0),(1),(2),(3)],
   [(4),(5),(6),(7)],
   [(8),(9),(10),(11)],
   [(12),(13),(14),(15)]
   ]
   ```

3. Reshape m4x4 as 2-by-8:

   ```
   reshape(m4x4,<val:double>[i=0:7,8,0,j=0:1,2,0]);
   ```

   This query returns:

   ```
   [
   [(0),(1)],
   [(2),(3)],
   [(4),(5)],
   [(6),(7)],
   [(8),(9)],
   [(10),(11)],
   [(12),(13)],
   [(14),(15)]
   ]
   ```

Name

reverse — Reverse values in each array dimension

Synopsis

```
SELECT * INTO target_array FROM source_array;
```

Summary

The reverse operator reverses all the values of each dimension in an array.

Example

This example reverses a 3×3 matrix.

1. Create a 3×3 array m3x3:

   ```
   CREATE ARRAY m3x3<val:double>[i=0:2,3,0,j=0:2,3,0];
   ```

2. Put values of 0–8 into m3x3:

   ```
   store(build(m3x3,i*3+j),m3x3);
   ```

   ```
   [
   [(0),(1),(2)],
   [(3),(4),(5)],
   [(6),(7),(8)]
   ]
   ```

3. Reverse the values in m3x3:

   ```
   reverse(m3x3);
   ```

   This query outputs:

   ```
   [
   [(8),(7),(6)],
   [(5),(4),(3)],
   [(2),(1),(0)]
   ]
   ```

Name

sample — Select random array chunks

Synopsis

```
SELECT * FROM sample(array,probability);
```

Summary

Example

This example selects random chunks from a 1-dimensional 3-chunk array.

1. Create a 1-dimensional array with dimension size of 6 and chunk size of 2:

   ```
   CREATE ARRAY vector1<val:double>[i=0:5,2,0];
   ```

2. Put values of 0–5 into vector1:

   ```
   store(build(vector1,i),vector1);
   ```

3. Sample chunks from the array with the probability of 1/3 that a chunk is included>

   ```
   sample(vector1,.3);
   ```

Name

save — Save array data to a file

Synopsis

```
AFL% save(array,filepath)
```

Summary

The AFL save operator works like the AQL SAVE clause. It saves the data from the cells of a SciDB array into a file.

Example

This example creates a a matrix with two attributes and saves the cell values to a file.

1. Create a 2-dimensional array containing values 100–108:

   ```
   store(build(<val:double>[i=0:2,3,0,j=0:2,3,0],i*3+j+100),array1);
   ```

2. Create a 2-dimensional array containing values 200–208:

   ```
   store(build(<val:double>[i=0:2,3,0,j=0:2,3,0],i*3+j+200),array2);
   ```

3. Join array1 and array2 and store the output in an array storage_array:

   ```
   store(join(array1,array2),storage_array);
   ```

   This query outputs:

   ```
   [
   [(100,200),(101,201),(102,202)],
   [(103,203),(104,204),(105,205)],
   [(106,206),(107,207),(108,208)]
   ]
   ```

4. Save the contents of storage_array to a file.

   ```
   save(storage_array,'/tmp/storage_array.txt');
   ```

   The contents of storage_array.txt are:

   ```
   {0,0}
   [
   [(100,200),(101,201),(102,202)],
   [(103,203),(104,204),(105,205)],
   [(106,206),(107,207),(108,208)]
   ]
   ```

Name

scan — Display cell values

Synopsis

```
SELECT * FROM scan(array);
```

Summary

The scan operator displays to contents of each cell in an array. You can use scan with a WHERE clause to view subsets of large arrays. The output of the scan operator is an array the same size as the input operator. To supress display of empty cells, set the iquery -o sparse option.

Example

This example selects the second row from an array and shows the cell values in that row.

1. Create a 3×3 array m3x3:

   ```
   CREATE ARRAY m3x3<val:double>[i=0:2,3,0,j=0:2,3,0];
   ```

2. Put values of 0–8 into m3x3:

   ```
   store(build(m3x3,i*3+j),m3x3);
   ```

3. Use scan in a FROM clause to display the middle row of m3x3:

   ```
   SELECT val FROM scan(m3x3) WHERE i=1;
   ```

   This query outputs:

   ```
   [
   [(),(),()],
   [(3),(4),(5)],
   [(),(),()]
   ]
   ```

4. You can supress the empty cells in the output by setting the iquery output to sparse:

   ```
   quit;
   iquery -o sparse
   AQL% SELECT val FROM scan(m3x3) WHERE i=1;
   {1,0}[[{1,0}(3),{1,1}(4),{1,2}(5)]]
   ```

Name

setopt — Set/get configuration option value at runtime.

Synopsis

```
setopt ( option-name [ , new-option-value ] )
```

This operator is designed for internal use.

Summary

Set/get configuration option value at runtime. Option value should be specified as string. If new value is not specified, then values of this configuration option at all instances are printed. If new value is specified, then value of option is updated at all instances and result array contains old and new values of the option at all instances.

Name

show — Show array schema

Synopsis

```
SELECT * FROM show(array);
```

Summary

The show operator returns an array's schema. This is useful if you are changing array dimensions with nested statements.

Example

Show the schema that results from several nested operations:

```
store(subarray(build(
 <val:double>[i=0:2,3,0,j=0:3,4,0,k=0:4,5,0],
 j+k),1,1,2,2,3,3),output_array);
show(output_array);
```

The schema of output_array is:

```
[("output_array<val:double> [i=0:1,3,0,j=0:2,4,0,k=0:1,5,0]")]
```

Name

slice — Select subset of array along a plane

Synopsis

```
SELECT * FROM slice(array,dimension1,index1[dimension2,index2,...]);
```

Summary

The slice operator takes a sample of cells along a specified plane of an array. The result is a slice of the input array corresponding to the given coordinate value(s). Number of dimensions of the result array is equal to the number of dimensions of input array minus number of specified dimension, and the coordinate value should be a valid dimension value of the input array.

Example

This example selects the middle column from a 3×3 array.

1. Create a 3×3 array m3x3:

   ```
   CREATE ARRAY m3x3<val:double>[i=0:2,3,0,j=0:2,3,0];
   ```

2. Put values of 0–8 into m3x3:

   ```
   store(build(m3x3,i*3+j),m3x3);
   ```

   ```
   [
   [(0),(1),(2)],
   [(3),(4),(5)],
   [(6),(7),(8)]
   ]
   ```

3. Select the middle column of m3x3:

   ```
   slice(m3x3,j,1);
   ```

   This query outputs:

   ```
   [(1),(4),(7)]
   ```

Name

sort — Sort by attribute value

Synopsis

```
SELECT * FROM sort(array,attribute,option);
```

Summary

Sort a one-dimensional array by one or more attributes. The sort attributes are specified using a 1-based attribute number. The default is ascending order. Set the option argument to desc to sort in descending order.

Example

Sort a set of random values from lowest to highest:

```
sort(build(<val:double>[i=0:9,10,0],random()%10),val);
```

```
[(0),(1),(3),(4),(4),(5),(6),(7),(8),(9)]
```

Name

stdev — Standard deviation

Synopsis

```
SELECT * FROM stdev(array,attribute,dimension1,dimension2,...)
```

Summary

Note

The stdev operator provides the same functionality as the stdev aggregate. See the stdev aggregate reference page for more information.

Example

This example finds the standard deviation of each row of a 2-dimensional array.

1. Create a 1-attribute, 2-dimensional array called m3x3:

   ```
   CREATE ARRAY m3x3 <val:double>[i=0:2,3,0,j=0:2,3,0];
   ```

2. Store values of random values between 0 and 1 in m3x3:

   ```
   store(build(m3x3,random()%9/10.0),m3x3);
   ```

   ```
   [
   [(0.5),(0.6),(0)],
   [(0.8),(0.8),(0.4)],
   [(0.1),(0.8),(0.6)]
   ]
   ```

3. Select the standard deviation of each row of m3x3:

   ```
   var(m3x3,val,i);
   ```

   This query returns:

   ```
   [(0.321455),(0.23094),(0.360555)]
   ```

Name

store — Store query output in a SciDB array

Synopsis

```
store(operator(operator_args),target_array);
```

Summary

store is a write operator, that is, one of the AFL operations that can update an array. Each execution of store causes a new version of the array to be created. When an array is removed, so are all its versions.

store() can be used to save the resultant output array into an existing/new array. It can also be used to duplicate an array (by using the name of the source array in the first parameter and target_array in the second parameter).

Note

The AFL store operator provides the same functionality as the AQL SELECT * INTO ... FROM ... statement.

Example

Build and store a 2-dimensional, 1-attribute matrix of zeros:

```
store(build(<val_double>[i=0:2,3,0,j=0:2,3,0],0),zeros_array);
```

You can change the name of the array zeros_array to ones_array and the cell values to 1 with a store statement:

```
store(build(zeros_array,1),ones_array);
```

Build and store a 2-dimensional, 1-attribute matrix of random numbers between 1 and 10:

```
store(build(random_array,random()%10),random_array);
```

```
[
[(6),(8),(3)],
[(6),(5),(1)],
[(6),(1),(3)]
]
```

You can update the array with a different set of random numbers by re-running the store statement:

```
store(build(random_array,random()%10),random_array);
```

```
[
[(4),(5),(6)],
[(5),(4),(6)],
[(8),(4),(2)]
]
```

Name

subarray — Select contiguous area of cells

Synopsis

```
SELECT * FROM subarray(array,boundary_coord_1,boundary_coord_2,...)
```

Summary

Subarray selects a block of cells from an input array. The result is an array whose shape is defined by the boundary coordinates specified by the subarray arguments. A boundary coordinate pair must be specified for every dimension of the input array.

Example

This example selects the values from the last two columns and the last two rows of a 4×4 matrix.

1. Create an array called m4x4:

   ```
   CREATE ARRAY m4X4 <val:double>[i=0:3,4,0,j=0:3,4,0];
   ```

2. Store values of 0–15 in m4x4:

   ```
   store(build(m4x4,i*4+j),m4x4);
   ```

   This query outputs:

   ```
   [
   [(0),(1),(2),(3)],
   [(4),(5),(6),(7)],
   [(8),(9),(10),(11)],
   [(12),(13),(14),(15)]
   ]
   ```

3. Return an array containing the cells that were in both the last two columns and the last two rows on m4x4:

   ```
   subarray(m4x4,2,2,3,3);
   ```

   This query returns:

   ```
   [
   [(10),(11)],
   [(14),(15)]
   ]
   ```

Name

substitute — Substitute new value for null values in an array

Synopsis

```
SELECT * FROM substitute(null_array,substitute_array);
```

Summary

Substitute null values in one array with non-null values from another array. The arrays must have the same dimension start index.

Example

This example replaces all null values in an array with zero.

1. Create an array m4x4_null with a nullable attribute:

   ```
   CREATE ARRAY m4x4_null <val:double null>[i=0:3,4,0,j=0:3,4,0];
   ```

2. Store null in the second row of m4x4_null and 100 in all the other cells:

   ```
   store(build(m4x4_null,iif(i=1,null,100)),m4x4_null);
   ```

3. Create a single-cell array called substitute_array

   ```
   CREATE ARRAY substitute_array <missing:double>[i=0:0,1,0];
   ```

4. Put value 0 into substitute_array:

   ```
   store(build(substitute_array,0),substitute_array);
   ```

5. Use the substitute operator to replace the null-valued cells in m4x4_null with 0-valued cells:

   ```
   substitute(m4x4_null,substitute_array);
   ```

   This query outputs:

   ```
   [
   [(100),(100),(100),(100)],
   [(0),(0),(0),(0)],
   [(100),(100),(100),(100)],
   [(100),(100),(100),(100)]
   ]
   ```

Limitation

The substitute operator can only take single-attribute arrays as inputs.

Name

sum — Sum attribute values

Synopsis

```
SELECT * FROM sum(array,attribute[,dimension])
```

Summary

Note

The sum operator offers the same functionality as the sum aggregate. See sum aggregate reference page for more information.

Example

This example sums the columns and rows of a 3×3 array.

1. Create a 1-attribute, 2-dimensional array called m3x3:

   ```
   CREATE ARRAY m3x3 <val:double>[i=0:2,3,0,j=0:2,3,0];
   ```

2. Store values of 0–8 in m3x3:

   ```
   store(build(m3x3,i*3+j),m3x3);
   ```

   ```
   [
   [(0),(1),(2)],
   [(3),(4),(5)],
   [(6),(7),(8)]
   ]
   ```

3. Sum the values of m3x3 along dimension j. This sums the columns of m3x3:

   ```
   sum(m3x3,val,j);
   ```

   This query outputs:

   ```
   [(9),(12),(15)]
   ```

4. Sum the values of m3x3 along dimension i. This sums the rows of m3x3:

   ```
   sum(m3x3,val,i);
   ```

   This query outputs:

   ```
   [(3),(12),(21)]
   ```

Name

thin — Select data from an array dimension at fixed intervals

Synopsis

```
SELECT * FROM thin(array,start_1,step_1,start_2,step_2,...);
```

Summary

The thin operator selects regularly spaced elements of the array in each dimension. The selection criteria are specified by the starting dimension value *`start_1`* and the number of cells to skip using *`step_1`* for each dimension of the input array. The dimension chunk size must be evenly divisible by the step size.

Example

This example selects every

1. Create an array m6x6:

   ```
   CREATE ARRAY m6x6 <val:double>[i=0:5,6,0,j=0:5,6,0];
   ```

2. Put values of 1–35 into m6x6:

   ```
   store(build(m6x6,i*6+j),m6x6);
   ```

   ```
   [
   [(0),(1),(2),(3),(4),(5)],
   [(6),(7),(8),(9),(10),(11)],
   [(12),(13),(14),(15),(16),(17)],
   [(18),(19),(20),(21),(22),(23)],
   [(24),(25),(26),(27),(28),(29)],
   [(30),(31),(32),(33),(34),(35)]
   ]
   ```

3. Select every other column of m6x6, starting at the first column;

   ```
   thin(m6x6,0,1,0,2);
   ```

   This query outputs:

   ```
   [
   [(0),(2),(4)],
   [(6),(8),(10)],
   [(12),(14),(16)],
   [(18),(20),(22)],
   [(24),(26),(28)],
   [(30),(32),(34)]]
   ```

4. Select every other row from m6x6, starting at the first row;

   ```
   thin(m6x6,0,1,0,2);
   ```

   This query outputs:

   ```
   [
   ```

```
[(0),(1),(2),(3),(4),(5)],
[(12),(13),(14),(15),(16),(17)],
[(24),(25),(26),(27),(28),(29)]
]
```

5. Select every other value from m6x6, starting at the second column;

```
thin(m6x6,1,2,1,2);
```

This query outputs:

```
[
[(7),(9),(11)],
[(19),(21),(23)],
[(31),(33),(35)]
]
```

Name

transpose — Matrix transpose

Synopsis

```
SELECT * FROM transpose(array)
```

Summary

The transpose operator accepts an array which may contain any number of attributes and dimensions. Attributes may be of any type. If the array contains dimensions d1, d2, d3, ..., dn the result contains the dimensions in reverse order dn, ..., d3, d2, d1.

Example

This example transposes a 3×3 matrix.

1. Create a 1-attribute, 2-dimensional array called m3x3:

   ```
   CREATE ARRAY m3x3 <val:double>[i=0:2,3,0,j=0:2,3,0];
   ```

2. Store values of 0–8 in m3x3:

   ```
   store(build(m3x3,i*3+j),m3x3);
   ```

   ```
   [
   [(0),(1),(2)],
   [(3),(4),(5)],
   [(6),(7),(8)]
   ]
   ```

3. Transpose m3x3:

   ```
   transpose(m3x3);
   ```

   This query outputs:

   ```
   [
   [(0),(3),(6)],
   [(1),(4),(7)],
   [(2),(5),(8)]]
   ```

Name

unload_library — Unload a plugin

Synopsis

```
unload_library('library_name')
```

Summary

Unload a plug-in from the current SciDB instance.

Note

The unload_library operator provides the same functionality as the AQL UNLOAD LIBRARY '*library_name*' statement.

Example

This example loads and unloads the example plug-in librational.so.

```
load_library('librational')
unload_library ('librational')
```

The file extension is not included in the library name.

Name

unpack — Transform multidimensional array to single dimension

Synopsis

```
SELECT * INTO vector FROM unpack(array,attribute_name)
```

Summary

The unpack operator unpacks a multidimensional array into a single-dimensional array creating new attributes to represent source array dimension values. The result array has a single zero-based dimension and arguments combining attributes of the input array. The name for the new single dimension is passed to the operator as the second argument.

Example

This example takes 2-dimensional, 1-attribute array and outputs a 1-dimensional, 3-attribute array.

1. Create a 1-attribute, 2-dimensional array called m3x3:

   ```
   CREATE ARRAY m3x3 <val:double>[i=0:2,3,0,j=0:2,3,0];
   ```

2. Store values of 0–8 in m3x3:

   ```
   store(build(m3x3,i*3+j),m3x3);
   ```

   ```
   [
   [(0),(1),(2)],
   [(3),(4),(5)],
   [(6),(7),(8)]
   ]
   ```

3. Create a new attribute called val2 containing values 100–108 and store the resulting array as m3x3_2attr:

   ```
   store(apply(m3x3,val2,val+100),m3x3_2attr);
   ```

   This query outputs:

   ```
   [
   [(0,100),(1,101),(2,102)],
   [(3,103),(4,104),(5,105)],
   [(6,106),(7,107),(8,108)]
   ]
   ```

4. Unpack m3x3_2attr into a 1-dimensional array.

   This query outputs:

   ```
   [
   (0,0,0,100),
   (0,1,1,101),
   (0,2,2,102),
   ```

```
(1,0,3,103),
(1,1,4,104),
(1,2,5,105),
(2,0,6,106),
(2,1,7,107),
(2,2,8,108)
]
```

The first two values in each cell are the dimensional indices, and the second two are the attribute values.

Name

var — Variance

Synopsis

```
SELECT * FROM var(array,attribute)
```

Summary

The var operator returns the variance of a set of values taken from an array attribute.

Note

The var operator provides the same functionality as the var aggregate. See the var aggregate reference page for more information.

Example

This example finds the variance of each row of a 2-dimensional array.

1. Create a 1-attribute, 2-dimensional array called m3x3:

   ```
   CREATE ARRAY m3x3 <val:double>[i=0:2,3,0,j=0:2,3,0];
   ```

2. Store values of random values between 0 and 1 in m3x3:

   ```
   store(build(m3x3,random()%9/10.0),m3x3);
   ```

   ```
   [
   [(0.5),(0.6),(0)],
   [(0.8),(0.8),(0.4)],
   [(0.1),(0.8),(0.6)]
   ]
   ```

3. Select the variance of each row of m3x3:

   ```
   var(m3x3,val,i);
   ```

   This query returns:

   ```
   [(0.103333),(0.0533333),(0.13)]
   ```

Name

versions — Show array versions

Synopsis

```
SELECT * FROM versions(array);
```

Summary

The versions operator lists all versions of an array in the SciDB namespace. The output of the versions command is a list of versions, each of which has a version ID and a datestamp which is the date and time of creation of that version.

Example

This example creates an array, updates it twice, and then returns the first version of the array.

1. Create an array called m1:

   ```
   CREATE ARRAY m1 <val:double>[i=0:9,10,0];
   ```

2. Store 1 in each cell of m1:

   ```
   store(build(m1,1),m1);
   ```

3. Update every cell to have value 100:

   ```
   store(build(m1,100),m1);
   ```

4. Use the versions command to see the two versions of m1 that you created:

   ```
   versions(m1);
   ```

5. Use the scan operator and the '@1' array name extension to display the first version of m1.

   ```
   scan(m1@1);
   ```

   This query outputs:

   ```
   [(1),(1),(1),(1),(1),(1),(1),(1),(1),(1)]
   ```

Name

window — Compute aggregates over moving window

Synopsis

```
SELECT * FROM window(array,grid_1,grid_2,...,grid_N,
aggregate_call_1[,aggrgegate_call_2, ...]
```

Summary

Compute one or more aggregates of any of an array's attributes over a moving window.

Note

The AFL window operator provides the same functionality as the AQL SELECT ... FROM ... WINDOW statement. See the User's Guide chapter on Aggregates for more information.

Example

This example calculates a running sum for a 3×3 window on a 4×4 array.

1. Create an array called m4x4:

   ```
   CREATE ARRAY m4X4 <val:double>[i=0:3,4,0,j=0:3,4,0];
   ```

2. Store values of 0–15 in m4x4:

   ```
   store(build(m4x4,i*4+j),m4x4);
   ```

   This query outputs:

   ```
   [
   [(0),(1),(2),(3)],
   [(4),(5),(6),(7)],
   [(8),(9),(10),(11)],
   [(12),(13),(14),(15)]
   ]
   ```

3. Return the maximum and minimum values on a moving 3×3 window on m4x4:

   ```
   window(m4x4,3,3,max(val),min(val));
   ```

   This query returns:

   ```
   [
   [(5,0),(6,0),(7,1),(7,2)],
   [(9,0),(10,0),(11,1),(11,2)],
   [(13,4),(14,4),(15,5),(15,6)],
   [(13,8),(14,8),(15,9),(15,10)]
   ]
   ```

Name

xgrid — Expand single array element to grid

Synopsis

```
SELECT * FROM xgrid(array,scale_1[,scale_2,..., scale_N])
```

Summary

The xgrid operators scales an input array by repeating cells of the original array specified number of times in a contiguous subregion. xgrid takes one *scale* argument for every dimension in *array*. The output array has the same number of dimensions and attributes as the input array.

Example

This example scales each cell of a 2-dimensional array into a 2×2 subarray.

1. Create an array called m3x3:

   ```
   CREATE ARRAY m3x3 <val:double> [i=0:2,3,0,j=0:2,3,0];
   ```

2. Put values of 0–8 into m3x3:

   ```
   store(build(m3x3,i*3+j),m3x3);
   ```

3. Expand each cell of m3x3 into a 2×2 subgrid. Store the resulting array as m6x6:

   ```
   store(xgrid(m3x3,2,2),m6x6);
   ```

   This query returns:

   ```
   [
   [(0),(0),(1),(1),(2),(2)],
   [(0),(0),(1),(1),(2),(2)],
   [(3),(3),(4),(4),(5),(5)],
   [(3),(3),(4),(4),(5),(5)],
   [(6),(6),(7),(7),(8),(8)],
   [(6),(6),(7),(7),(8),(8)]
   ]
   ```