High Performance Data Management with PyTables & Family

Francesc Alted
falted@carabos.com

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Outline

- Who are we?
- What is PyTables and why does it exist?
- ViTables (interactive demonstration)
- What’s new in PyTables 0.9
- Reliability and performance in 0.9
- CSTables (PyTables goes Client-Server)
- Final remarks
Who are we?

Cáribos is the company committed to PyTables development and deployment

We have years of experience in designing software solutions for handling extremely large data sets

What we offer:
- Commercial support for PyTables & companion products
- PyTables-based applications
- Consulting services for managing complex data environments
Motivation

- Many scientific applications need to save and read very large quantities of data. Analysing this data effectively is a challenge.
- Computers are powerful enough to deal with very large data sets. But, can people handle that and not expire in the attempt?

Requirements of a data management application:
- Analysis is an iterative process: interactivity
- Reading the data over and over: efficiency
- Solid and flexible framework that would allow the user to provide a clear structure to his data
- Easy management

PyTables is a Python package designed with these requirements in mind!
What does PyTables offer?

- **Interactivity**
  - The user can take immediate action based on previous feedback
  - This greatly accelerates the process of data mining

- **Efficiency**
  - Very important when interactivity is an issue

- **Hierarchical structure**
  - Break your data into smaller, related chunks
  - Intuitive way to categorize data

- **Object-oriented interface**
  - Datasets become objects that can be easily manipulated
  - In a hierarchical structure, objects facilitate data browsing
When PyTables can be useful

Situations where one has to store and efficiently retrieve very large amounts of data. Some examples:

- **Scientific applications**
  - Meteorology
  - Astronomy
  - Genetics
  - Medicine (Physiological sensors, ...)

- **Industrial applications**
  - Data acquisition of sensors
  - Real time monitoring

- **Data acquisition from IT applications**
  - Tracing data from routers
  - System log monitoring
  - Security alerts (Firewalls, IDS, ...)

What’s behind PyTables

PyTables relies on powerful software to achieve its goals:

- Python -- Everyone here knows that (2.2 version needed because generators are heavily used)
- HDF5 -- General purpose library and file format for storing scientific data
- numarray -- Next generation of the well-known Numerical Python package
- Pyrex -- Tool to make Python extensions with a Python-like syntax
ViTables (visualize PyTables datafiles)

Easy-to-use graphical user interface for viewing data (and metadata) in PyTables files

- It uses PyTables and the excellent Qt graphic library, so it is available on most platforms (ViTables runs on most Unix, Linux, MacOSX and Windows systems)

- Can be used as well as a starting point for creating PyTables-based graphical applications (prototyping)
ViTables main features

- Visualizes the object tree graphically
- Can open an independent view for each dataset
- Offers information about the metadata present in nodes
- Can open several files simultaneously
- Can move or copy datasets or complete sub-hierarchies from one group to another, even between different files
- Great browseable documentation
- As a PyTables companion, it deals very well with extremely large datasets (tables exceeding one billion rows)
ViTables interactive demonstration
Future plans for ViTables

- Implement graphical row modification & deletion in tables and arrays
- Create an automated test suite
- Improve stability and reliability
- Improve the documentation
- Create a binary installer for Windows (MacOSX?) platforms
- Release the version 1.0 (most likely dual-licensed) by the end 2004
What’s new in PyTables 0.9?

- Table values can be modified (yes, finally :)
- In-kernel selections
- Indexed selections
- Improved speed for large row sizes in Table objects
Modification of values in tables

In PyTables 0.9 two ways of modifying values in Table objects have been introduced

- **Row modification**
  
  ```
  rows = numarray.records.array([[457,'db1',1.2],[6,'de2',1.3]],
  formats="i4,a3,f8")
  ```
  
  ```
  table.modifyRows(start=1, stop=4, step=2, rows=rows)
  ```
  
  ```
  table[1:4:2] = rows  # shortcut
  ```

- **Column modification**
  
  ```
  table.modifyColumns(start=1, step=2, columns=[[2,3,4]], names=['col1'])
  ```
  
  ```
  table.cols.col1[1:7:2] = [2,3,4]  # shortcut
  ```
  
  # Modify several columns at time:
  
  ```
  columns = [['aaa','bbb','ccc'], [1.2, .1, .3]]
  ```
  
  ```
  table.modifyColumns(start=1, columns=columns, names=['col2', 'col3'])
  ```
In-kernel & Indexed selections

In-kernel selections:
- Like regular selections, but more efficient
- Condition is passed "as is" to the PyTables C extension
- Can be between 2 to 5 times faster than regular selections

Indexed selections:
- An index is created in the same data file
- Can be 5 to 500 times faster than traditional selects (but slower under some situations!)

All scalar types are supported (string, ints, floats and booleans)

Limitation: you can only pass conditions on a single column
In-kernel & Indexed selections syntax

SQL syntax

```python
e = cursor.execute(select sum(col1) from table where 3 < col2 <= 20)
```

Traditional search in PyTables:

```python
# Compute the sum of the column "col1" values that pass the selection
e = sum([row['col1'] for row in table if 3 < row['col2'] <= 20])
# Using generator expressions to save memory (you need Python 2.4!)
# e = sum(row['col1'] for row in table if 3 < row['col2'] <= 20)
```

In-kernel selection:

```python
e = sum(row['col1'] for row in table.where(3<table.cols.col2<=20))
```

Indexed selection:

```python
table.cols.col2.createIndex()  # Create the index
e = sum(row['col1'] for row in table.where(3<table.cols.col2<=20))
```

Mixed selections:

```python
e = sum(row['col1'] for row in table.where(3<table.cols.col2<=20)
if row['col3'] == 2 and row['col1'] > 4)
```

Always pass the more restrictive selections to the "where" method!
How fast is fast?

Several benchmarks have been conducted in order to know if PyTables is competitive with existing tools to save data persistently.

Comparisons have been made with SQLite (a fast relational database).

The benchmarks tested writing and selecting table data under a series of conditions.

Two basic parameters were changed in each test to comparatively measure I/O performance:

- The number of rows in the table
- The selection method (regular iterator, in-kernel and indexed)
The normal distribution has been chosen because it should be more like "real life" data.
Benchmark platform description

- AMD Opteron @ 1.6 GHz and 8 GB RAM
- IDE disk @ 7200 RPM
- PyTables 0.9 (beta)
- Python 2.3.3
- HDF5 1.6.2
- numarray 1.0
- SuSe GNU/Linux 8.0 (Enterprise)
- Linux Kernel 2.4.21
- GCC 3.2.2 compiler
- SQLite 2.8.14
- PySQLite 0.5
PyTables vs SQLite (time to write entries)
PyTables vs SQLite (time to create index)

The graph compares the index creation time for PyTables, PyTables zlib, and SQLite, with the y-axis representing time in seconds and the x-axis representing the number of rows. The lines illustrate how the time to create an index increases as the number of rows grows.
PyTables vs SQLite (disk usage w/index)

Total file size (data+indexes)

Size (MB) vs Number of rows graph

- PyTables
- PyTables zlib
- SQLite

Graph shows the total file size in MB against the number of rows for each database system.
PyTables vs SQLite (non-indexed search)

![Graph showing the comparison between PyTables standard, PyTables in-kernel, and SQLite in terms of selection time (without indexation) versus number of rows. The x-axis represents the number of rows ranging from 1000 to 1e+09, and the y-axis represents time in seconds ranging from 1e-04 to 1e+09. The graph compares the performance of the three systems across different data sizes, with PyTables standard generally showing better performance than SQLite, and PyTables in-kernel showing the best performance.]
PyTables vs SQLite (indexed search)
Comparison between the different selection modes in PyTables

- Standard
- In-kernel
- Indexed (index not in cache)
- Indexed (index in cache)
Conclusions from benchmark

■ Writing
  • PyTables typically write more than 100 times faster than SQLite
  • SQLite files occupy 3 to 5 times more space than PyTables; if compression is used, these ratios can double
  • SQLite time indexing cost for very large tables is prohibitive; however, PyTables keeps this cost relatively small

■ Reading
  • In-kernel selections can be up to 5 times faster than standard and up to 10 times faster than SQLite (for very large tables)
  • Indexed selections can be up to 500 times faster than standard
  • When the index is in-cache, SQLite can be up to 10 times faster than PyTables for moderately large table sizes (but does not scale well)

PyTables indexing can be applied to much larger tables than SQLite
Reliability

- Developing software suited for production environments is a very important design goal.
- Test suite based on UnitTest, the standard Python unit testing framework.
- A lot of effort has been put into making the test suite as complete as possible.
- More than 2000 tests units (represents more than 12000 lines of pure code) are now incorporated; more will be added and quality will only improve as PyTables evolves.
PyTables limitations and plans for future

- Object elements cannot be related to other elements (i.e. no references support)
- Table elements cannot be of variable length
- Deleting rows in tables is slow
- Modifying elements in *Array objects is not yet supported
- Optimization of some corner cases
CSTables: PyTables goes Client-Server

- CSTables is the client-server implementation of PyTables
- Provides the possibility of using PyTables remotely and concurrently
- Uses the Twisted (www.twistedmatrix.org) package’s excellent networking capabilities
CSTables usage

- The API is much the same as the PyTables API
  - PyTables API:
    ```python
    import tables
    fileh=tables.openFile("file.h5")
    print fileh.root.table.cols.col1[:]
    fileh.close()
    ```
  - CSTables API:
    ```python
    import client, commontables
c=client.TablesClient()
root=c.connect()
gltables=root.getTablesApplicationRoot()
fileh=gltables.openFile("file.h5")
print fileh.root.table.cols.col1[:]
fileh.close()
    ```

- Some (very few) instructions added to control:
  - Server execution parameters
  - Concurrent mode execution
CSTables client cache

- CSTables caches some of the metadata of the PyTables object tree
- When a client makes a change to the metadata, this change is pushed to the other clients’ caches
- Easy to control which attributes should be cached and which shouldn’t
- Object is to cache primarily read-only attributes
  - Caveat emptor: Caching attributes that are updated very often generates more traffic than attributes that are not cached at all
CSTables concurrency issues

- CSTables does not provide threading or asynchronous features yet.
- So, how does it deal with several requests at a time?
- Large data read and write requests are split into smaller chunks.
- This considerably improves server response time.
- In addition, CSTables provides a lock mechanism that allows applications to explicitly put a lock on a node or on an entire subtree.
- The locks offer different blocking access modes: READ, WRITE, and ALL.
CSTables status & availability

- The main features are already implemented and working (95% of PyTables tests already pass)
- Focus now is on checking & debugging possible errors, as well as providing a 100% compatibility with PyTables API
- This will allow to have a client version of ViTables very easily
- A public release is scheduled for the end of this year
- Future directions: Java interface, SOAP support, threading, asynchronous communications
Final remarks

- PyTables & family allows you to process your data interactively and quickly.

- Its powerful writing, reading and selection features makes an interpreted language like Python powerful enough to get maximum performance.

- The development of ViTables & CSTables has given an unexpected momentum to the PyTables project. Together they form an excellent tool suite to deal with extremely large amounts of data.
PyTables is for real work!

- It has been production-ready for over a year. Its API is fairly stable; < 1.0 release numbering only shows that all the desired functionality is not yet implemented.

- It comes with complete documentation both in doc strings format as well as a high quality 90 pages user’s manual in PDF and HTML formats.

- Download the latest version (0.9 will be released in September) and use it for free from:

  http://pytables.sourceforge.net
Credits

Carabos Crew:
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Questions?

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