Ophidia big data analytics framework

Dr. Sandro Fiore
Director of the CMCC Advanced Scientific Computing Division

on behalf of the Ophidia Team
The Ophidia project

Ophidia ([http://ophidia.cmcc.it](http://ophidia.cmcc.it)) is a CMCC Foundation research project addressing big data challenges for eScience.

It provides support for declarative and server-side data analysis exploiting high performance computing paradigms and database approaches.

Exploits a multidimensional data model providing the data cube abstraction for access and analysis of scientific n-dimensional data.
Paradigm shift from client- to server-side

Volume, variety, velocity are key challenges for big data in general and for climate change science in particular. Client-side, sequential and disk-based workflows are three limiting factors for the current scientific data analysis.

Ophidinia Architecture: end-user view

**Oph_Term**: a commands interpreter with no GUI (like bash), serving as a client for the Ophidinia framework

**Ophidinia framework**: Server-side processing

Through the **oph_term** we “send” commands to the framework
Ophidia Architecture (sw stack view)

**Front end**

- OPHIDIA Server
  - Declarative language
  - Standard interfaces

**Compute layer**

- Compute nodes
  - Compute node 1
  - Compute node 2
  - Compute node n

**I/O layer**

- I/O Nodes
  - I/O node 1
  - I/O node 2
  - I/O node n

- MySQL Service
- MySQL Service
- MySQL Service
- MySQL Service
- MySQL Service
- MySQL Service
- MySQL Service
- MySQL Service

**I/O server instance**

- New storage model
- Array-based primitives

**Storage layer**

- New storage model
- Partitioning/hierarchical data mng

**System catalog**

- OphidiaDB
- Data Store
- Data Store
- Data Store
- Data Store
- Data Store
- Data Store
Ophidia in a nutshell

✔ Big data stack for scientific data analysis

✔ **Features:** time series analysis (array-based analysis), data subsetting (by value/index), data aggregation, model intercomparison, **OLAP**, etc.

✔ Use of parallel operators and parallel I/O

✔ **Support for complex workflows / operational chains**

✔ Extensible: **simple API** to support framework extensions like new operators and array-based primitives
  ✔ currently 50+ operators and 100+ primitives provided

✔ **Multiple interfaces** available (WS-I, GSI/VOMS, **OGC-WPS**).

✔ Programmatic access via C and **Python APIs**

✔ Support for both **batch & interactive** data analysis
Data abstraction: cube space perspective (OLAP)

Manage the Ophidia file system

<table>
<thead>
<tr>
<th>CMD</th>
<th>BEHAVIOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>cd</td>
<td>change directory</td>
</tr>
<tr>
<td>mkdir</td>
<td>create a new folder</td>
</tr>
<tr>
<td>rm</td>
<td>remove an empty folder or hide (logically delete) a container</td>
</tr>
<tr>
<td>ls</td>
<td>list subfolders and containers in a folder</td>
</tr>
<tr>
<td>mv</td>
<td>move/rename a folder or a container</td>
</tr>
</tbody>
</table>

Metadata associated to the datacubes

<table>
<thead>
<tr>
<th>TYPE</th>
<th>CONTENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text</td>
<td>Plain text metadata</td>
</tr>
<tr>
<td>image</td>
<td>Binary string representation of an image</td>
</tr>
<tr>
<td>video</td>
<td>Binary string representation of a video</td>
</tr>
<tr>
<td>audio</td>
<td>Binary string representation of an audio stream</td>
</tr>
<tr>
<td>url</td>
<td>Text representing an URL</td>
</tr>
</tbody>
</table>

User metadata information

Metadata provenance

- https://ophidia.cmcc.it:8443/162/169 (ROOT)
  - https://ophidia.cmcc.it:8443/162/170 (oph_reduce)
    - https://ophidia.cmcc.it:8443/162/171 (oph_merge)
  - https://ophidia.cmcc.it:8443/162/172 (oph_aggregate2)
  - https://ophidia.cmcc.it:8443/162/173 (oph_rollup)
    - https://ophidia.cmcc.it:8443/162/174 (oph_reduce)
  - https://ophidia.cmcc.it:8443/162/176 (oph_aggregate)
    - https://ophidia.cmcc.it:8443/162/177 (oph_aggregate)

Search & Discovery
Experiment: climate indicators processing

- In the CLIPC project, processing chains for data analysis are being implemented with Ophidia to compute climate indicators.

- **First set of indicators** includes: $\text{T}_{\text{Nn}}$, $\text{T}_{\text{Nx}}$, $\text{T}_{\text{Xn}}$, $\text{T}_{\text{Xx}}$
  - Input files: 12GBs ($\text{TasMin}$ & $\text{TasMax}$)
  - Workflows have been already implemented

- **Parallel approach**
  - Inter-parallelism & Intra-parallelism
Workflow JSON representation

```
"tasks": [
  {
    "name": "Loop on tasmin and tasmax cubes",
    "operator": "oph_for",
    "arguments": [ "name=cube", "counter=1:2", "values=${1}|${2}x", "parallel=yes" ]
  },
  {
    "name": "Compute operation over time",
    "operator": "oph_reduce2",
    "arguments": [ "cube=${cube}", "dim=time", "concept level=M", "midnight=00", "operation=$3", "container=tmp" ],
    "dependencies": [ {"task": "Loop on tasmin and tasmax cubes"} ]
  },
  {
    "name": "Conversion from Kelvin to Celsius degrees",
    "operator": "oph_apply",
    "arguments": [ "query=oph_sum_scalar('oph_float', 'oph_float', measure, -273.15)" ],
    "dependencies": [ {"task": "Compute operation over time", "type": "single"} ]
  },
  {
    "name": "Loop for subset months",
    "operator": "oph_for",
    "arguments": [ "name=index", "counter=1:12", "values=Jan|Feb|Mar|Apr|May|Jun|Jul|Aug|Sep|Oct|Nov|Dec", "label" ],
    "dependencies": [ {"task": "Conversion from Kelvin to Celsius degrees", "type": "single"} ]
  },
  {
    "name": "Subset on 1-month",
    "operator": "oph_subset",
    "arguments": [ "subset_dims=time", "subset_filter=${index:12:end}" ],
    "dependencies": [ ]
]
```
Workflow submission

```bash

[27, 6380] >> view 247

[Response]:
Workflow Status

OPH_STATUS_COMPLETED

Workflow Progress

NUMBER OF COMPLETED TASKS | TOTAL NUMBER OF TASKS |
----------------------------|----------------------|
   82                      |        82            |

Workflow Task List

<table>
<thead>
<tr>
<th>OPH JOB ID</th>
<th>SESSION CODE</th>
<th>WORKFLOW ID</th>
<th>MARKER ID</th>
<th>PARENT MARKER ID</th>
<th>TASK NAME</th>
<th>TYPE</th>
<th>EXIT STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://193.284.199.174/ophidia/sessions/3769923831130223251449455166146380/experiment?247#3145">http://193.284.199.174/ophidia/sessions/3769923831130223251449455166146380/experiment?247#3145</a></td>
<td>3769923831130223251449455166146380</td>
<td>247</td>
<td>3145</td>
<td>3144</td>
<td>Loop on tasmin and tasmmax cubes</td>
<td>SIM</td>
<td>OPH STATUS COMPLETED</td>
</tr>
<tr>
<td><a href="http://193.284.199.174/ophidia/sessions/3769923831130223251449455166146380/experiment?247#3146">http://193.284.199.174/ophidia/sessions/3769923831130223251449455166146380/experiment?247#3146</a></td>
<td>3769923831130223251449455166146380</td>
<td>247</td>
<td>3146</td>
<td>3144</td>
<td>Compute operation over time (1)</td>
<td>SIM</td>
<td>OPH STATUS COMPLETED</td>
</tr>
<tr>
<td><a href="http://193.284.199.174/ophidia/sessions/3769923831130223251449455166146380/experiment?247#3147">http://193.284.199.174/ophidia/sessions/3769923831130223251449455166146380/experiment?247#3147</a></td>
<td>3769923831130223251449455166146380</td>
<td>247</td>
<td>3147</td>
<td>3144</td>
<td>Compute operation over time (2)</td>
<td>SIM</td>
<td>OPH STATUS COMPLETED</td>
</tr>
<tr>
<td><a href="http://193.284.199.174/ophidia/sessions/3769923831130223251449455166146380/experiment?247#3148">http://193.284.199.174/ophidia/sessions/3769923831130223251449455166146380/experiment?247#3148</a></td>
<td>3769923831130223251449455166146380</td>
<td>247</td>
<td>3148</td>
<td>3144</td>
<td>Conversion from Kelvin to Celsius degrees (1)</td>
<td>SIM</td>
<td>OPH STATUS COMPLETED</td>
</tr>
<tr>
<td><a href="http://193.284.199.174/ophidia/sessions/3769923831130223251449455166146380/experiment?247#3149">http://193.284.199.174/ophidia/sessions/3769923831130223251449455166146380/experiment?247#3149</a></td>
<td>3769923831130223251449455166146380</td>
<td>247</td>
<td>3149</td>
<td>3144</td>
<td>Conversion from Kelvin to Celsius degrees (2)</td>
<td>SIM</td>
<td>OPH STATUS COMPLETED</td>
</tr>
</tbody>
</table>
```
Tier1 indicators using Ophidia

Snow on/off – Length of snow season

✔ Dataset time range: 1979-2012
✔ 50 GB of input data
✔ 434 tasks performed
✔ 99 NetCDF output files
Tier1 indicators using Ophidia

SWE monthly average

- Dataset time range: 1979-2008
- 1.7 GB of input data
- 76 tasks performed
- 12 NetCDF output files
**Tier1 indicators using Ophidia**

**SST mean, anomaly, climatology mean**

- ✔ Dataset time range: 1991-2010
- ✔ 350GB of input data
- ✔ 87 tasks performed
- ✔ Expected 12x51MB + 2x12GB of output files

![Monthly sea surface temperature anomaly](image)
Provenance management (PID-based)

RDA proposal submitted on extending Ophidia with RDA PID recommendation (collaboration with DKRZ)
Ophidia & INDIGO-DataCloud

- **An H2020 project** approved in January 2015 in the EINFRA-1-2014 call
  - 11.1M€, 30 months (*from April 2015 to September 2017*)
- **Who:** 26 **European partners** in 11 European countries
  - Coordination by the Italian National Institute for Nuclear Physics (INFN)
  - Including developers of distributed software, industrial partners, research institutes, universities, e-infrastructures
- **What:** **develop an open source Cloud platform** for computing and data (“DataCloud”) tailored to science.
- **For:** **multi-disciplinary scientific communities**
  - E.g. structural biology, earth science, physics, bioinformatics, cultural heritage, astrophysics, life science, climatology
- **Where:** deployable on **hybrid (public or private) Cloud infrastructures**
  - INDIGO = **INtegrating Distributed data Infrastructures for Global Exploration**
- **Why:** answer to the technological **needs of scientists** seeking to easily exploit distributed Cloud/Grid compute and data resources.
Testbed environment for running multi-model experiments (precipitation trend analysis)

More on this topic in the afternoon talk at 5.30pm
BIGSEA: cloud and QoS based vertical and horizontal elasticity for big data systems
Resources [http://ophidia.cmcc.it]

Ophidia is a CMCC Foundation research project addressing big data challenges for eScience. It provides support for data-intensive analysis exploiting advanced parallel computing techniques and smart data distribution methods. It exploits an array-based storage model and a hierarchical storage organisation to partition and distribute multidimensional scientific datasets over multiple nodes. The Ophidia analytics framework can be exploited in different scientific domains (e.g. Climate Change, Earth Sciences, Life Sciences) and with very heterogeneous sets of data.
Resources (II)

PyOphidia 1.2.1

Python bindings for the Ophidia Data Analytics Platform

PyOphidia is a GPU-based Python package for interacting to the Ophidia platform. It is an alternative to Oph_Term, the no-GUI interpreter component bundled with Ophidia, and a convenient way to submit SOAP/HTTPS requests to an Ophidia server or to develop your own client using Python.

It runs on Python 2.6, 2.7, and 3.4, has no dependencies and is pure-Python.
Thanks

http://ophidia.cmcc.it

@OphidiaBigData

www.youtube.com/user/OphidiaBigData