rootpy: Pythonic ROOT

rootpy.org

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for the rootpy developers

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“What’s the problem?”

Why would we even consider developing a layer on top of PyROOT?

- PyROOT is mainly bindings (although with some pythonization).
- Python’s dynamic nature provides **many possibilities not currently realized by PyROOT**. One might argue a majority of these high-level pythonizations are **beyond the scope of what PyROOT should offer.**
- Certain tasks require awkward code and are error-prone. Similar workarounds are implemented by many people in multiple places.
  Why not solve these issues once and for all?
- There is a lack of integration of ROOT with the vast and growing ecosystem of scientific Python packages.
  Why not enable users to benefit from both the power of ROOT and what is offered by the scientific Python community?

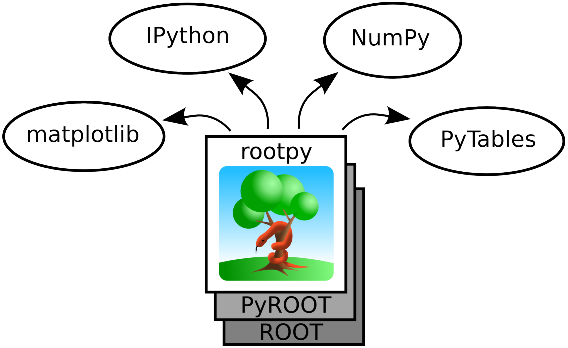
Scientific Python Applications

"Can I perform complicated analysis with Python?"
You certainly can!

- ROOT with PyROOT
- Interactive computing: IPython
- Powerful and fast array manipulation: NumPy
- Feature-rich publication-quality plotting: matplotlib
- Efficiently and easily handle large amounts of data: PyTables
- General scientific library: scipy
- Flexible data analysis and manipulation: pandas
- Symbolic mathematics: sympy
- Statistical models and tests: statsmodels
- Fitting: iminuit and sherpa
- Astronomy: astropy
- Image processing: scikit-image
- Machine learning: scikit-learn
- Search for packages on the Python Package Index

Introducing rootpy…

- rootpy aims to provide a ***more pythonic layer*** on top of the PyROOT bindings and to take advantage of advanced features of the Python language.
- **rootpy does not intend to recreate ROOT** or to *severely* alter the default behaviour of ROOT.
- **rootpy is not an analysis framework**, but rather a library that one's analysis framework might use.
- rootpy provides an **interface with the scientific Python packages**:



rootpy: key concepts and design philosophy

- Pythonized **classes in rootpy are subclasses of the corresponding ROOT classes** with the same (or similar) name, but without the “T”.
- ROOT methods may be overridden or new methods created to add functionality and objects may be decorated with additional properties.
- **Object names and titles are optional**. Unspecified names default to UUIDs.
- ROOT messages should be routed through Python’s logging system with **error messages raised as Python exceptions**.
- **Python has a garbage collector but C++ does not:** this can lead to strange issues. rootpy addresses these problems.
- Anywhere Python is typically slow we intend to use **compiled C extension modules**. Through the root_numpy package, rootpy provides very fast conversion of ROOT Trees into NumPy arrays as well as efficiently filling ROOT histograms with NumPy arrays.

“What does rootpy offer?”

rootpy.plotting	histogram, graphs, canvas, pad, legend, and style subclasses with additional pythonizations, including a matplotlib interface.
rootpy.tree	trees, chains, tree objects, tree models, cuts.
rootpy.io	file and directory subclasses, utilities.
rootpy.logger	route ROOT messages through Python’s logging module. ROOT error messages become Python exceptions.
rootpy.memory	utilities for monitoring TObject deletions and for keeping objects alive when out of scope in Python.
rootpy.interactive	a wait function for preventing Python from exiting until all canvases have been closed.
rootpy.stl	automatic STL dictionary compilation and caching.
rootpy.root2hdf5	conversion of ROOT files into HDF5.
rootpy.context	utilities for managing ROOT’s global state.

. . . and more . . .

See the root_numpy package for conversion of TTrees into NumPy arrays.

Histograms

PyROOT

```
from ROOT import TH3D
from array import array

# variable width bins
hist3d = TH3D('3d', '3d', 3, array('d', [0, 3, 10, 100]),
                          5, array('d', [2.3, 4.2, 5.8, 10, 20, 25.5]),
                          2, array('d', [-100, 0, 20]))
# ROOT is missing some constructors... (the following will not work)
hist3d = TH3D('3d', '3d', 3, 0, 5,
                          5, array('d', [2.3, 4.2, 5.8, 10, 20, 25.5]),
                          2, array('d', [-100, 0, 20]))
```

rootpy

```
from rootpy.plotting import Hist3D

# variable width bins
hist3d = Hist3D([0, 3, 10, 100], [2.3, 4.2, 5.8, 10, 20, 25.5], [-100, 0, 20])
# easy to mix variable and fixed width bins with rootpy
hist3d = Hist3D(3, 0, 5, [2.3, 4.2, 5.8, 10, 20, 25.5], [-100, 0, 20])
```

Histograms and Style

- rootpy reduces ROOT's histogram classes down to Hist, Hist2D, Hist3D.
- The appropriate ROOT base class is set *dynamically*:

```
>>> from rootpy.plotting import Hist2D
>>> hist = Hist2D(10, 0, 1, 5, 0, 1, type='F')
>>> hist.__class__.__bases__[-1].__name__
'TH2F'
```

- Attributes can be accessed via properties:

```
hist.title = 'Fit Result'
hist.fillstyle = 'solid'
color = hist.linecolor
```

- Colors can also be set using hex, RGB tuples, or SVG names:

```
hist.fillcolor = (32, 178, 170)
hist.linecolor = '#87cefa'
hist.markercolor = 'salmon'
```

Cuts

PyROOT

```
from ROOT import TCut

cut1 = TCut('a<10')
cut2 = TCut('b%2==0')

cut = TCut('(%s)&&(%s)' % (
    cut1.GetTitle(),
    cut2.GetTitle()))

print cut.GetTitle()
```

output:

```
(a<10)&&(b%2==0)
```

rootpy

```
from rootpy.tree import Cut

cut1 = Cut('a < 10')
cut2 = Cut('b % 2 == 0')

cut = cut1 & cut2
print cut

# expansion of ternary conditions
cut3 = Cut('10 < a < 20')
print cut3

# easily combine cuts arbitrarily
cut = ((cut1 & cut2) | - cut3)
print cut
```

output:

```
(a<10)&&(b%2==0)
(10<a)&&(a<20)
((a<10)&&(b%2==0))||(!((10<a)&&(a<20)))
```

PyROOT: Opening a TFile

```python
"""
ROOT is unable to open the file of course and emits an error message but an
exception is not raised at this point leading to (sometimes difficult to
interpret) issues downstream:
"""
from ROOT import TFile

myfile = TFile.Open("file_does_not_exist.root")
print myfile
myfile.Get("something")
```

```
Error in <TFile::TFile>: file file_does_not_exist.root does not exist
<ROOT.TFile object at 0x(nil)>
Traceback (most recent call last):
  File "file_open.py.tmp.py", line 13, in <module>
    myfile.Get("something")
ReferenceError: attempt to access a null-pointer
```

rootpy: Opening a TFile

```python
"""
rootpy routes ROOT messages through Python‘s logging system and raises error
messages as Python exceptions at the point of failure:
"""
from rootpy.io import root_open

myfile = root_open("file_does_not_exist.root")
print myfile
myfile.Get("something")
```

```
ERROR:ROOT.TFile.TFile] file file_does_not_exist.root does not exist
```

```
Traceback (most recent call last):
  File "file_open_rootpy.py.tmp.py", line 13, in <module>
    myfile = root_open("file_does_not_exist.root")
  File "/home/endw/.local/lib/python2.7/site-packages/rootpy/io/file.py", line 224, in root_open
    root_file = ROOT.TFile.Open(filename, mode)
  File "/home/endw/.local/lib/python2.7/site-packages/rootpy/io/file.py", line 224, in root_open
    root_file = ROOT.TFile.Open(filename, mode)
  File "/home/endw/.local/lib/python2.7/site-packages/rootpy/logger/roothandler.py", line 91, in python_logging_error_handler
    raise ROOTError(level, location, msg)
rootpy.ROOTError: level=3000, loc='TFile::TFile', msg='file file_does_not_exist.root does not exist'
```

An exception is raised at the point of failure: `root_open()`

rootpy: Navigating a TFile

```python
from rootpy.testdata import get_file

# use the test file shipped with rootpy
with get_file() as f:
    # access objects by name as properties of the current dir
    myhist = f.dimensions.hist2d
    # recursively walk through the file
    for path, dirs, objects in f.walk():
        # do something
        print path, dirs, objects
```

```
 ['dimensions', 'scales', 'means', 'graphs', 'gaps', 'efficiencies'] []
dimensions [] ['hist2d', 'hist3d']
scales [] ['hist1', 'hist3', 'hist2', 'hist4']
means [] ['hist1', 'hist3', 'hist2', 'hist4']
graphs [] ['tgrapherrors', 'tgraph2d', 'tgraphasymmerrors', 'tgraph']
gaps [] ['hist1', 'hist3', 'hist2', 'hist4']
efficiencies [] ['hist1', 'hist3', 'hist2', 'hist4', 'eff3v1', 'eff2v1', 'eff4v1']
```

PyROOT: Filling a TTree

```python
from ROOT import TTree, TFile
from array import array
from random import gauss

output_file = TFile.Open('output.root', 'recreate')
some_float = array('f', [0.])
some_int = array('i', [0])
tree = TTree('mytree', '')
tree.Branch('some_float', some_float, 'some_float/F')
tree.Branch('some_int', some_int, 'some_int/I')

for i in xrange(100):
    some_float[0] = gauss(0, 1)
    some_int[0] = i
    tree.Fill()

tree.Write()
output_file.Close()
```

rootpy: Filling a TTree

```python
from rootpy.tree import Tree
from rootpy.io import root_open
from random import gauss

f = root_open("test.root", "recreate")

tree = Tree("test")
tree.create_branches(
        {'some_float': 'F',
         'some_int': 'I'})

for i in xrange(10000):
    tree.some_float = gauss(.5, 1.)
    tree.some_int = i
    tree.fill()
tree.write()
f.close()
```

rootpy: Tree Models

Easily create complex trees by simple class inheritance (inspired by PyTables):

```python
from rootpy.tree import Tree
from rootpy.tree import TreeModel
from rootpy.types import FloatCol
from rootpy.types import IntCol

class FourVect(TreeModel):
    eta = FloatCol(default=-1111.)
    phi = FloatCol(default=-1111.)
    pt = FloatCol()
    m = FloatCol()

class Tau(FourVect):
    numtrack = IntCol()

class Event(Tau.prefix('tau1_'),
            Tau.prefix('tau2_')):
    event_number = IntCol()
    run_number = IntCol()

# tree = Tree('data', model=Event)
print Event
```

Branches are constructed according to the requested model:

```
event_number -> IntCol()
run_number -> IntCol()
tau1_eta -> FloatCol(default=-1111.0)
tau1_m -> FloatCol()
tau1_numtrack -> IntCol()
tau1_phi -> FloatCol(default=-1111.0)
tau1_pt -> FloatCol()
tau2_eta -> FloatCol(default=-1111.0)
tau2_m -> FloatCol()
tau2_numtrack -> IntCol()
tau2_phi -> FloatCol(default=-1111.0)
tau2_pt -> FloatCol()
```

Support for default values, automatic STL dictionaries, ROOT objects.

Memory issues? Solved.

PyROOT

```
from ROOT import TCanvas, TH1D

def make_plot():
    canvas = TCanvas('plot', 'plot',
                     700, 500)
    hist = TH1D('hist', 'plot',
                10, -3, 3)
    hist.FillRandom('gaus')
    hist.Draw()
    return canvas

canvas = make_plot()
# empty canvas since the histogram
# has been garbage collected!
canvas.Draw()
# hack to keep Python from exiting
# while the canvas is displayed
raw_input()
```

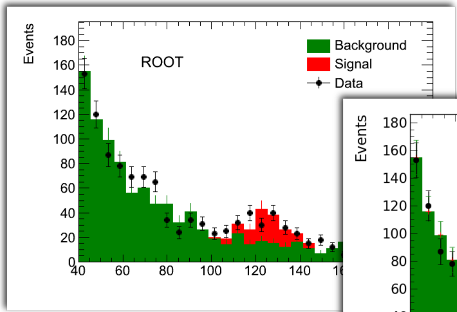
rootpy

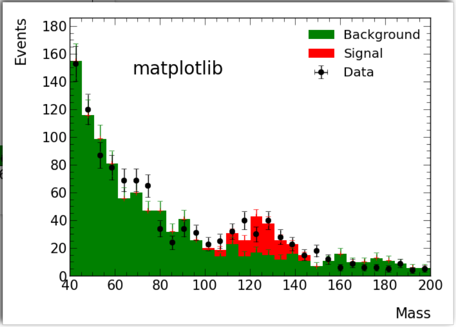
```
from rootpy.plotting import Canvas, Hist
from rootpy.interactive import wait

def make_plot():
    canvas = Canvas(700, 500)
    hist = Hist(10, -3, 3)
    hist.FillRandom('gaus')
    hist.Draw()
    return canvas

canvas = make_plot()
canvas.Draw()
wait()
```

Objects are kept alive as long as the Canvas is alive.
See rootpy's keepalive function.

rootpy: Interface with matplotlib

ROOT histograms can be drawn with matplotlib via rootpy's matplotlib interface:





matplotlib: highly customizable, multiple backends, uses your latex engine.

The future of rootpy

- Benefit from ROOT 6!
- Larger documentation coverage and more examples. **This is important!**
- Python 3 support.
- Better integration with the IPython prompt:
  - Full tab completion and helpful builtin commands like pylab.
  - Fetch documentation on-demand for a class/method/function.
- Automatic wrapping of ROOT methods by parsing method signatures:
  - If a method expects a TColor, rootpy can accept any matplotlib/ROOT color and convert it into a TColor before passing to the ROOT method.
  - Reduce the amount of code in rootpy.
- TMVA:
  - Ability to feed TMVA classifiers NumPy arrays.
- RooFit and RooStats:
  - Wrap RooArgSet as set() and RooArgList as list()?
  - Create RooDataSets from NumPy arrays.
- rootpy should serve as a **testing ground for new ideas**.

“How do I install rootpy?”

1. First install ROOT with PyROOT enabled.
2. Clone the rootpy repository with git:

   ```
   git clone git://github.com/rootpy/rootpy.git
   ```

   or checkout with svn (if you must…):

   ```
   svn checkout http://svn.github.com/rootpy/rootpy
   ```

3. Then install:

   ```
   cd rootpy
   python setup.py install --user
   ```

- The easiest way to install a released version is with pip:

  ```
  pip install --user rootpy
  ```

- See the README for full instructions.

How can you contribute?

- Development is community-driven.
- We use Git! See the rootpy collaboration on GitHub: github.com/rootpy
- Just fork rootpy into your own GitHub account and:

  ```
  git clone git@github.com:<username>/rootpy.git
  ```

  Then submit a pull request with your contribution.
- Contributions are reviewed by peers before merging into the main branch.
- All new code automatically triggers our test suite using Travis CI.

The Developers:

- Noel Dawe
- Peter Waller
- Piti Ongmongkolkul
- Christoph Deil
- Evan Friis
- Jeff Klukas

Where to find us:

- rootpy.org
- github.com/rootpy
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- rootpy-users@googlegroups.com