Developing Geospatial software with Python, Part 2

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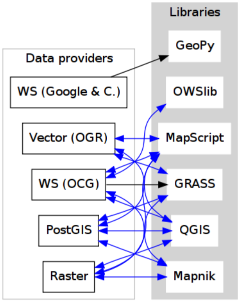
GFOSS Day, Foligno - 18/19 November 2010

Building blocks: overview



- architecture: pure python / binary wrappers, *pythonicity*
- application interaction: GUI / headless
- input/output formats
- performances and scalability (mostly unexplored)
- documentation, maturity, support, community

Building blocks: WebServices

- XML
- Json
- plain text
- REST

Only a selection from an huge set:

- OWS (OGC Web Services)
- GeoNames
- Google Maps
- Yahoo Maps

Building blocks: OGC Web Services

- OWSlib (client)

- Mapnik (server)
- Mapscript (both)
- QGIS (both)

Open Geospatial Consortium defines the following standards for geospatial web services (OWS):

- *WMS* (Web Map Service)
- *WFS* (Web Feature Service)
- *WCS* (Web Coverage Service)
- *CSW* (Catalogue Service for Web)
- *WPS* (Web Processing Service)
- many others...

KVP/XML requests

OGC WS: WMS

Web Map Service (WMS) is a standard protocol for serving georeferenced map images over the Internet that are generated by a map server using data (vector and cover) from a GIS database

OGC WS: WMS operations

- *GetCapabilities* - returns parameters about the WMS and the available layers (*)
- *GetMap* - with parameters provided (srs, format, width, eight, bbox, layers...) returns a map image (*)
- *GetFeatureInfo* - with parameters provided returns feature informations (**)
- *DescribeLayer*
- *GetLegendGraphic*

(*) basic WMS (**) queryable WMS

OGC WS: WMS GetMap operation

main parameters: layers, styles, srs, bbox, width, height, format

sample GetMap operation (output is an image):

http://wms.pcn.minambiente.it/cgi-bin/mapserv.exe?map=/ms_ogc/service/ortofoto_colore_06_f32.map&layers=ortofoto_

OGC WS: WFS

Web Feature Service (WFS) provides a standard interface allowing requests for geographical features across the web using platform-independent calls

The WFS specification defines interfaces for describing data manipulation operations of geographic features. Data manipulation operations include the ability to:

- Get or Query features based on spatial and non-spatial constraints
- Create a new feature instance (WFS-T)
- Delete a feature instance (WFS-T)
- Update a feature instance (WFS-T)

OGC WS: WFS operations

- GetCapabilities (1)
- DescribeFeatureType (1)
- GetFeature (1)
- GetGmlObject (2)
- Transaction (3)
- LockFeature (3)

1. basic WFS - read only
2. XLink WFS (complex features traversal)

3. transaction WFS (WFS-T)

OGC WS: WFS GetFeature operation

main parameters: typeName, maxfeatures, query...

sample GetFeature operation (output is GML)

http://wms.pcn.minambiente.it/cgi-bin/mapserv.exe?map=/ms_ogc/wfs/regioni_wfs_f33.map&service=WFS&typename=r

OGC WS: WCS

Web Coverage Service Interface Standard (WCS) provides an interface allowing requests for geographical coverages across the web using platform-independent calls

Operations:

- GetCapabilities
- DescribeCoverage
- GetCoverage

OGC WS: WCS GetCoverage operation

main parameters: coverage, crs, bbox, time, width, height, resx, resy, format

GetCoverage operation (output is a coverage):

http://my.host.com/cgi-bin/mapserv?map=mywcs.map&SERVICE=wcs&VERSION=1.0.0&REQUEST=GetCoverage&cov

Note: at least one time or bbox parameter is needed

OGC WS: CSW

Catalogue Service

- defines common interfaces to discover, browse, query and manage metadata about data, services, and other potential resources
- defines a query language (similar to the SQL "Where Clause") to be supported by all OGC Catalogue Interfaces in order to support search interoperability
- common queryable elements - request (subject, title, abstract, anytext (1), format, identifier, modified, type, boundingbox, CRS...)

- core returnable properties -response (title, creator, subject, description, publisher, contributor, date, type...)

OGC WS: CSW operations

Operations:

- GetCapabilities
- DescribeRecord
- GetDomain (*)
- GetRecords
- GetRecordById
- Transaction (*)
- Harvest

(*) optional implementations

OGC WS: CSW GetRecords operation

main parameters: outputFormat (XML, text, html), maxRecords, SortBy, Constraint

GetRecords operation (output is XML)

```
http://www.someserver.com/csw/csw.cgi?request=GetRecords&version=2.0.2&outputFormat=application/xml&outputSchema=http://www.opengis.net/cat/csw/2.0.2&namespace=csw:http://www.opengis.org/cat/csw&ResponseHandler="mailto:info@site.com&typeName=csw:Record&elementSetName=brief&constraintlanguage=CQLTEXT&constraint="csw:AnyText Like '%pollution%'"
```

OGC WS: WPS

- pyWPS

  Web Processing Server provides rules for standardizing how inputs and outputs (requests and responses) for geospatial processing services

Operations:

- *GetCapabilities* returns service-level metadata
- *DescribeProcess* returns a description of a process including its inputs and outputs
- *Execute* returns the output(s) of a process

Accepts parameters as GET, POST, SOAP

Building blocks - WS: GeoNames

- a geographical database that covers all countries and contains over eight million placenames
- license: Creative Commons Attribution 3.0
- both a web application and a big set of web services

GeoNames: Web Services

- License: CC
- REST, XML and JSON WSs
- *Premium* offer

Most notably:

- geocoding
- reverse geocoding
- place hierarchy

- places from bounding box
- wikipedia search
- postal code search
- elevation

GeoNames: example of API use

Regions of Italy:

http://ws.geonames.org/children?geonameId=3175395

Response:

```
<geonames style="MEDIUM">
    <totalResultsCount>20</totalResultsCount>
    <geoname>
    <toponymName>Abruzzo</toponymName>
    <name>Abruzzo</name>
    <lat>42.25</lat>
```

```
    <lng>13.75</lng>
    ...
```

Building blocks - WS: Google Maps

> [...] the Elevation API may only be used in conjunction with displaying results on a Google map; using elevation data without displaying a map for which elevation data was requested is prohibited.

- google map embedding (javascript API)
- google map webservices
- geocoding (and reverse geocoding)
- directions
- elevations
- places

Google Maps: example of API use

A geocoding request example:

http://maps.googleapis.com/maps/api/geocode/xml?address=123+via+Oberdan+Foligno,+Italy&sensor=true

Response:

```
<GeocodeResponse>
<status>OK</status>
<result>
<type>street_address</type>
<formatted_address>
Via Guglielmo Oberdan, 123, 06034 Foligno Perugia, Italy
</formatted_address>
...
<geometry>
    <location>
        <lat>42.9561745</lat>
        <lng>12.7090235</lng>
   </location>
```

. . .

Libraries & Tools

Libraries & Tools for the **pythonic geographer**

- QGIS
- GeoPy
- OWSLib
- MapNik
- MapScript
- PyWPS
- GRASS

Building blocks: QGIS

QGIS (Quantum GIS) is a *C++ Qt* cross-platform GIS desktop application with vector editing capabilities and python scripting support.

- python plugins (lot of)
- *standalone* python applications (headless or GUI)
- OGC WMS headless server

QGIS: standalone headless

Loading a vector layer

```
>>> # Application init
>>> from qgis import core
>>> core.QgsApplication.setPrefixPath("/usr", True)
>>> core.QgsApplication.initQgis()
>>> vlayer = core.QgsVectorLayer("regioni.shp", "regioni", "ogr")
>>> vlayer.isValid()
True
>>> # Add layer to registry
>>> core.QgsMapLayerRegistry.instance().addMapLayer(vlayer)
    <qgis.core.QgsVectorLayer object at 0x13be270>
>>> # Continue ...
```

QGIS: standalone (render)

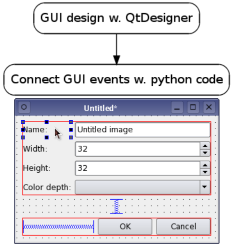
Rendering and image through *QGIS* API

```
>>> # ... from previous example
>>> from PyQt4 import QtGui, QtCore
>>> img = QtGui.QImage(QtCore.QSize(800,600), QtGui.QImage.Format_ARGB32_Premultiplied)
>>> p = QtGui.QPainter()
>>> p.begin(img)
True
>>> p.setRenderHint(QtGui.QPainter.Antialiasing)
>>> render = core.QgsMapRenderer()
>>> lst = [ vlayer.getLayerID() ]
>>> render.setLayerSet(lst)
>>> rect = core.QgsRectangle(render.fullExtent())
>>> rect.scale(1.1)
>>> render.setExtent(rect)
>>> render.setOutputSize(img.size(), img.logicalDpiX())
>>> img.size()
>>> p.isActive()
True
>>> render.render(p)
>>> p.end()
True
>>> img.save(wd + "/../images/regioni_qgis.png","png")
True
```

QGIS: result

QGIS: standalone GUI

- *pyQt4*
- *QtDesigner* (recommended)
- GUI programming skills



QGIS standalone GUI less is more

Minimal example: shapefile viewer

```
>>> from PyQt4 import QtGui, QtCore
>>> import sys, os
>>> from qgis import core, gui
>>> # QGIS application init
>>> core.QgsApplication.setPrefixPath('/usr', True)
>>> core.QgsApplication.initQgis()
>>> app = QtGui.QApplication(sys.argv)
>>> # Layer loading and canvas init
>>> l = core.QgsVectorLayer(sys.argv[1], os.path.basename(sys.argv[1]), 'ogr')
>>> l.isValid()
True
>>> canvas = gui.QgsMapCanvas()
>>> canvas.resize(800,600)
>>> core.QgsMapLayerRegistry.instance().addMapLayer(l)
>>> canvas.setExtent(l.extent())
>>> cl = gui.QgsMapCanvasLayer(l)
>>> canvas.setLayerSet([ cl ])
>>> canvas.show()
>>> retval = app.exec_()
>>> core.QgsApplication.exitQgis()
```

```
>>> sys.exit(retval)
```

QGIS: plugins

Powerful extensions to QGIS! Download from http://pyqgis.org

- start from a barebone plugin or use the Plugin builder
- create a GUI with *QtDesigner*
- connect GUI events with QGIS code
- control QGIS application from python code
- see: QGIS APIs http://qgis.org/api/

Geopy

Geopy (http://code.google.com/p/geopy/) provides an interface to external **geocoding** and **reverse geocoding** *webservices*

Providers:

- Google Maps
- Yahoo! Maps
- Windows Local Live (Virtual Earth)
- geocoder.us
- GeoNames
- MediaWiki pages (with the GIS extension)
- Semantic MediaWiki pages

Geopy: installation and usage

```
$ sudo easy_install geopy
```

```
>>> from geopy import geocoders
>>> g = geocoders.Google()
>>> g.geocode('via anelli 12, milano')
(u'Via Luigi Anelli, 12, 20122 Milan, Italy', (45.452325000000002, 9.1927447999999998))
>>> g.geocode('otherworld')
GQueryError: No corresponding geographic location could be found for the specified location, possibly because the address is relatively new, or because it may be incorrect.
```

Geopy: risultati multipli

```
>>> g.geocode('xyz')
ValueError: Didn't find exactly one placemark! (Found 6.)
>>> for l in g.geocode('xyz', exactly_one=False):
...     l
...
(u'S Xyz Rd, Pickford, MI 49774, USA', (46.118099999999998, -84.321274599999995))
(u'XYZ Liquor, 295 US Highway 17 S, Bartow, FL 33830, USA', (27.895257999999998, -81.828790999999995))
(u'XYZ Restaurant, 80 Seawall Rd, Southwest Harbor, ME 04679-4024, USA', (44.269646999999999, -68.322371000000004))
(u'XYZ Trading, 7018 Harwin Dr, Houston, TX 77036-2114, USA', (29.718654999999998, -95.507260000000002))
(u'Xyz Exterminating, PO Box 1643, Grand Island, NE 68802-1643, USA', (40.93, -98.340000000000003))
(u'\uff38\uff39\uff3a\u6c34\u6ca2', (39.156194399999997, 141.1596222))
```

Geopy: reverse

svn version required for reverse functions

```
$ svn checkout http://geopy.googlecode.com/svn/branches/reverse-geocode geopy
$ cd geopy/
$ sudo python setup.py install
```

```
>>> (loc, point) = g.geocode('via anelli 1, milano')
>>> point
(45.453902599999999, 9.1930519000000004)
>>> g.reverse(point)
(u'Via Luigi Anelli, 1, 20122 Milan, Italy',
(45.453902599999999, 9.1930519000000004))
```

OWSLib

OWSLib Makes WxS Suck Less. A library to consume OGC(TM) web services.

- lxml

Standard	Version(s)
OGC WMS	1.1.1
OGC WFS	1.0.0, 1.1.0
OGC WCS	1.0.0, 1.1.0

OGC WMC	1.1.0
OGC SOS	1.0.0 (not complete)
OGC CSW	2.0.2
OGC Filter	1.1.0
OGC OWS Common	1.0.0, 1.1.0, 2.0
NASA DIF	9.7
FGDC CSDGM	1998
ISO 19139	2003/2007
Dublin Core	1.1

OWSLib: installation and usage

```
$ sudo easy_install OWSLib
```

```
>>> from owslib.wms import WebMapService
>>> wms = WebMapService('http://wms.pcn.minambiente.it/cgi-bin/mapserv.exe?map=/ms_ogc/service/ortofoto_colore_06_f32.map', version='1.1.1')
>>> list(wms.contents)
['ortofoto_colore_06', 'watermark']
>>> wms.contents['ortofoto_colore_06']
>>> md.crsOptions
Out[7]: ['EPSG:32632']
>>> wms['ortofoto_colore_06'].boundingBox
(298457.0, 3914540.0, 1327000.0, 5239710.0, 'EPSG:32632')
>>> wms['ortofoto_colore_06'].boundingBoxWGS84
(6.3349900000000003,
35.034300000000002,
19.840800000000002,
47.310899999999997)
```

OWSLib: usage

```
>>> wms.getOperationByName('GetMap').formatOptions
['image/png',
'image/gif',
'image/png; mode=24bit',
'image/jpeg',
'image/wbmp',
'image/tiff',
'image/svg+xml']
>>> img = wms.getmap( layers= ['ortofoto_colore_06'],  bbox = (514832, 5034338, 515032, 5034548), srs = 'EPSG:32632', size=(300, 300), format = 'image/jpeg')
>>> img.geturl()
'http://wms.pcn.minambiente.it/cgi-bin/mapserv.exe?map= ...'
>>> outfile = open('duomo.jpg', 'wb')
>>> outfile.write(img.read())
>>> outfile.close()
```

OWSLib: result

Mapnik

Mapnik is a *C*++ Toolkit for developing mapping applications. Above all Mapnik is about making beautiful maps. Suitable for both server and desktop.

- Nice *utils* programs
- Rendering engine for OSM
- Itegrated WMS server
- Lack of documentation
- XML configuration for styles
- No SLD support
- QuantumNik QGIS plugin

Installation

```
$ sudo apt-get install libmapnik0.7 mapnik-utils python-mapnik
```

Installation from source is a nightmare: lot of dependencies

Mapnik: python map

```
import mapnik
m = mapnik.Map(300,300,"+proj=latlong +datum=WGS84")
m.background = mapnik.Color('steelblue')
s = mapnik.Style()
r = mapnik.Rule()
r.symbols.append(mapnik.PolygonSymbolizer(mapnik.Color('#f2eff9')))
r.symbols.append(mapnik.LineSymbolizer(mapnik.Color('rgb(50%,50%,50%)'),0.1))
s.rules.append(r)
# Make PIEDMONT red
r = mapnik.Rule()
r.filter = mapnik.Filter("[regione] = 'PIEMONTE'")
r.symbols.append(mapnik.PolygonSymbolizer(mapnik.Color('#ff0000')))
s.rules.append(r)
m.append_style('My Style',s)
lyr = mapnik.Layer('world',"+proj=latlong +datum=WGS84")
lyr.datasource = mapnik.Shapefile(file = '../data/regioni')
lyr.styles.append('My Style')
```

```
m.layers.append(lyr)
m.zoom_to_box(lyr.envelope())
mapnik.render_to_file(m, '../images/regioni_mapnik.png', 'png256')
```

Mapnik: layer inspection

Can be useful for dynamic rules building

```
# .. continues from previous example
>>> feature = lyr.datasource.all_features()[0]
>>> for p in feature.attributes:
...     p
('boundingbo', u'')
('cod_reg', 1)
('cod_rip1', 11)
('cod_rip2', 21)
('gid', 1)
('objectid', 1)
```

```
('regione', u'PIEMONTE')
('shape_area', 25388746287.599998)
('shape_len', 1334295.0100499999)
```

Mapnik: XML mapfile

```
<?xml version="1.0" encoding="utf-8"?>
<!DOCTYPE Map>
<Map bgcolor="steelblue" srs="+proj=latlong +datum=WGS84">

  <Style name="My Style">
    <Rule>
      <PolygonSymbolizer>
        <CssParameter name="fill">#f2eff9</CssParameter>
      </PolygonSymbolizer>
      <LineSymbolizer>
        <CssParameter name="stroke">rgb(50%,50%,50%)</CssParameter>
        <CssParameter name="stroke-width">0.1</CssParameter>
      </LineSymbolizer>
    </Rule>
    <Rule>
        <Filter>[regione] = 'PIEMONTE'</Filter>
      <PolygonSymbolizer>
```

```xml
        <CssParameter name="fill">#ff0000</CssParameter>
      </PolygonSymbolizer>
    </Rule>
  </Style>

  <Layer name="regioni" srs="+proj=latlong +datum=WGS84">
    <StyleName>My Style</StyleName>
    <Datasource>
      <Parameter name="type">shape</Parameter>
      <Parameter name="file">../data/regioni</Parameter>
    </Datasource>
  </Layer>

</Map>
```

Mapnik: result

Mapscript

Python bindings to **UMN MapServer** (*C*)

- complete bindings: full access to MapServer power
- not very *pythonic*
- http://mapserver.org/mapscript/

Installation:

```
$ sudo apt-get install python-mapscript
```

Mapscript: usage

I hate mapfiles ;)

```
import mapscript
map = mapscript.mapObj(  )
map.name = 'Test Map'
map.setSize(300, 300)
map.setExtent(-180.0,-90.0,180.0,90.0)
map.imagecolor.setRGB(80, 180, 80)
map.units = mapscript.MS_DD
layer = mapscript.layerObj(map)
layer.name = "regioni"
layer.type = mapscript.MS_LAYER_POLYGON
layer.status = mapscript.MS_DEFAULT
layer.data =  'data/regioni'
```

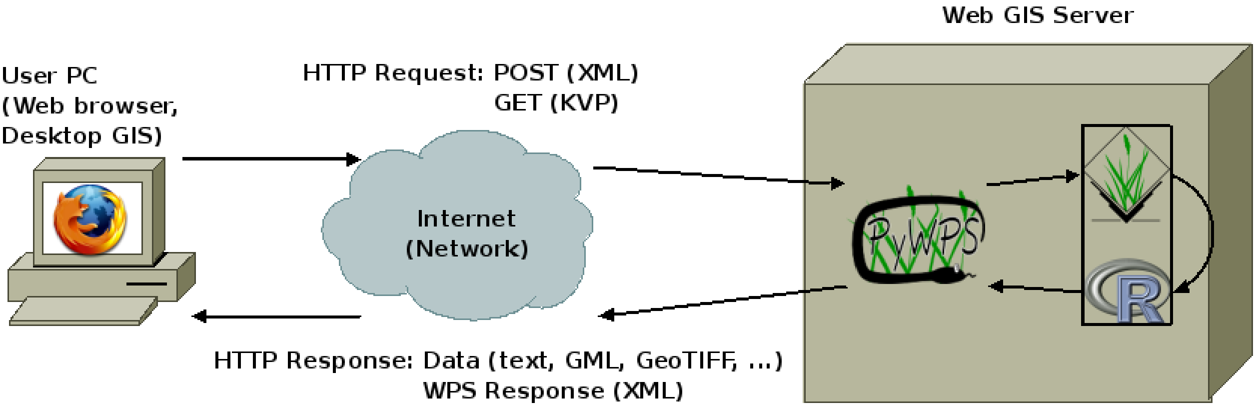
```
lass1 = mapscript.classObj(layer)
class1.name = "Regioni"
style = mapscript.styleObj(class1)
style.outlinecolor.setRGB(100, 100, 100)
style.color.setRGB(200, 200, 200)
extent = layer.getExtent()
map.setExtent(extent.minx, extent.miny, extent.maxx, extent.maxy)
mapimage = map.draw()
mapimage.save('images/mapscript_map.png')
```

MapScript: result

pyWPS

(Python Web Processing Service) is an implementation of the *Web Processing Service* standard from Open Geospatial Consortium. It offers an environment for programming own processes (geofunctions or models) which can be accessed from the public. The main advantage of PyWPS is, that it has been written with native support for *GRASS* GIS.

- http://pywps.wald.intevation.org/



GRASS

Powerful **raster** GIS analysis (mixed: *C*, *Python* etc.)

- GRASS Python scripting library
- GRASS ctypes bindings (low level GRASS library calls)

- lot of environment requirements
- difficult to configure for an headless use

GRASS: scripting

Environment setup

```
import sys, os

GISBASE = '/usr/lib/grass64/'
wd = os.path.dirname(os.path.realpath(__file__))

# Setup environment
sys.path.append( GISBASE + 'etc/python/' )
os.environ['GISBASE'] = GISBASE
os.environ['GISRC'] = '/home/' + os.environ['USER'] + '/.grassrc6'
```

```
os.environ['PATH'] = os.environ['PATH'] + ':' + GISBASE + 'scripts/'
os.environ['PATH'] = os.environ['PATH'] + ':' + GISBASE + 'bin/'
os.environ['LD_LIBRARY_PATH'] = GISBASE + 'lib/'
os.environ['GIS_LOCK'] = "%s" % os.getpid()

import grass.script as grass
```

GRASS: scripting (2)

Running commands

```
print grass.run_command('g.version', flags = 'r')
print grass.run_command('v.in.ogr', flags = 'l', dsn = wd + '/../data/regioni.shp')
print grass.run_command('v.in.ogr', flags='c', layer = 'regioni', location = 'regioni', output = 'regioni',  dsn = wd + '/../data/regioni.shp')
# Set region resolution
print grass.run_command('g.mapset', mapset='PERMANENT', location='regioni')
print grass.run_command('g.region', res = 0.02)
print grass.run_command('g.list',  type = 'vect')
print grass.run_command('v.to.rast', input='regioni', output='regioni', column='cod_reg')
print grass.run_command('r.out.png', input='regioni', output= wd + '/../images/regioni_grass.png')
```

GRASS: result

GRASS: ctypes

```
$ export LD_LIBRARY_PATH='/usr/lib/grass64/lib/'
```

Ctypes reads LD_LIBRARY_PATH at python interpreter startup: non way to set this from the script.

```
from ctypes import *
cgrass = CDLL("libgrass_gis.so")
cgrass.G__gisinit()
```

Links

- QGIS
- http://www.qgis.org/wiki/Python_Bindings
- http://www.qgis.org/pyqgis-cookbook/
- http://desktopgisbook.com/Creating_a_Standalone_GIS_Application_1
- http://www.dimitrisk.gr/qgis/creator/
- GRASS
- http://grass.osgeo.org/programming6/pythonlib.html
- http://grass.osgeo.org/grass64/manuals/html64_user/index.html
- Mapnik
- http://mapnik.org
- http://code.google.com/p/mapnik-utils/
- http://bitbucket.org/springmeyer/quantumnik/

- PyWPS
- http://pywps.wald.intevation.org/