Implementation of OGC's WPS standard: PyWPS

Jachym Cepicky

June 12, 2007

In this file, you can found the description of installation and configuration of PyWPS script. At the and, you can learn, how to add your own process to the list of processes. The file describes most recent version of PyWPS (*2.0.0*), available in subversion respository.

PyPWS project has been started on April 2006 with support of DBU – Deutsche Bundesstiftung Umwelt (`http://dbu.de`) and with help of GDF-Hannover (`http://gdf-hannover.de`) and Help Service Remote Sensing (`http://www.bnhelp.cz`) companies. Initial author is Jachym Cepicky (`http://les-ejk.cz`).

Contents

1 Introduction

PyWPS (Python Web Processing Service) is implementation of Web Processing Service standard from Open Geospatial Consortium.

It has been started on Mai 2006 as project supported by DBU. It offers environment for programming own process (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. Access GRASS modules via web interace should be as easy as possible.

Processes can be written using GRASS GIS, but usage of other programs is also possible. Usage together with R package or GDAL or PROJ tools.

PyWPS is written in Python programming language, your processes must use this language too.

PyWPS Homepage can be found at http://pywps.wald.intevation.org. PyWPS Wiki is hosted on http://pywps.ominiverdi.org.

1.1 How it works

PyWPS is an translator application between client (Web Browser, Desktop GIS, command line tool, ...) and working tool installed on the server. PyWPS does no work by it self. As working tool, GRASS GIS, GDAL, PROJ, R and other programs can be used.
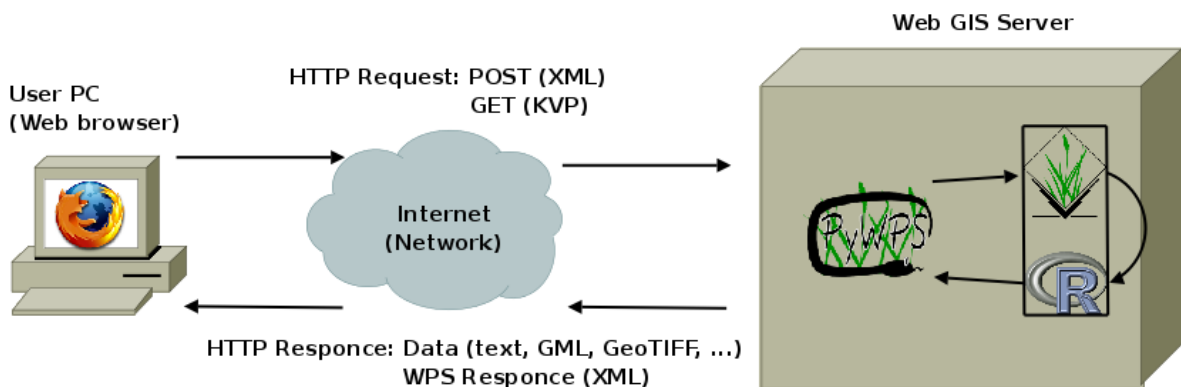
Figure 1: How does PyWPS work: GRASS GIS is in this case working tool

2 Bugs

Known bugs and limitations to

- Sometimes, when there is e.g. SyntaxError in the process, teporary file `/tmp/pywps*` is not deleted, which ledts to `ServerBussy` exception and the files have to be removed by hand.

- If inputs are of type `LiteralValue` and it's type is string, it is not controlled properly. Take care on your inputs and do not use it directly in scripts to avoid your server to be hacked.

3

Please report all problems or unexpected handeling either via pywps mailing list[1] or using PyWPS bugtracker[2].

3 Installation

Required packages:

- python

- python-xml

Recommended packages:

- Web Server (e.g. Apache) – http://httpd.apache.org - You will need an web server, to be able to execute processes from remote computers.

- GIS GRASS – http://grass.itc.it - Geographical Resources Analysis Support System (GRASS) is Open Source GIS, which provides more then 350 modules for raster and vector (2D, 3D) data analysis. PyWPS is written with native support for GRASS and it's functions.

- PROJ.4 – http://proj.maptools.org - Cartographic Projections library used in various Open Source projects, such as GRASS, UMN MapServer, QGIS and others. It can be used e.g. for data transformation.

- GDAL/OGR – http://gdal.org - translator library for raster geospatial data formats, is used in various projects for importing, exporting and transformation between various raster and vector data formats.

- R – http://www.r-project.org - is a language and environment for statistical computing and graphics.

3.1 Installation the quick 'n' dirty way

For installing pywps to your server simply unzip the archive to the directory, where cgi programs are allowed to run. You can also use current repository version.

```
$ cd /usr/lib/cgi-bin/
$ tar xvzf /tmp/pywps-VERSION.tar.gz
$ pywps/wps.py
```

3.2 Installation the 'clean' way

Unzip the package

```
$ tar -xzf pywps-VERSION.tar.gz
```

and run

---

[1]PyWPS - development list
[2]PyWPS Bug tracker

```
$ python setup.py install
```

Several binary packages for Linux distributios are also avaliable on PyWPS site[3].

3.3   Testing after installation

For test, just run `wps.py` in your command line:

```
$ ./wps.py
Content-type: text/xml

<?xml version="1.0" ?>
<ExceptionReport version="1.0.0" xmlns="http://www.opengis.net/ows"
        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
        <Exception exceptionCode="MissingParameterValue" locator="request"/>
</ExceptionReport>
```

If you got some other message, like e.g.:

```
Traceback (most recent call last):
  File "trunk/index.py", line 53, in ?
    from Wps import wpsexceptions
  File "/home/jachym/prog/pywps/trunk/Wps/wpsexceptions.py", line 8, in ?
    from xml.dom.minidom import Document
ImportError: No module named xml.dom.minidom
```

Than something is wrong with your Python installation or with the program. This message means, that the xml.dom.minidom package is not installed in your system.

4   Configuration

Before you start to tune your pywps program, you should get your copy of OpenGIS(R) Web Processing Service document (OGC 05-007r4) version 0.4.0 from
http://www.opengeospatial.org/specs/?page=specs

NOTE: Note, that the configuration option are CASE SENSITIVE

Pywps configuration takes places in two files. The files are actually python scripts, so it does not harm, if you have some experience in python programming language. But you should be able to setup the program without any python knowledge.

The first file is in `etc/settings.py` and (optional) the second file is `etc/grass.py` which has to be setuped if you do want to use GRASS GIS modules in your scripts. Some special "tuning" can be done in `processes/__init__.py` file. You can allways obtain original configuration files from `Wps/default settings.py` and `Wps/default grass.py`.

---

[3]http://pywps.wald.intevation.org

4.1 `etc/settings.py`

This file has got two sections: WPS and serverSettings

In the `WPS` section, the main configuration is set, which appears mostly in GetCapabilities request. The *mandatory* parameters, which should be set up are (with default/recommend values):

```python
WPS = {
    'version': "0.4.0",
    'ServiceIdentification': {
        'Title':"Jachym's WPS server",
        'ServiceType':"WPS",
        'ServiceTypeVersion':"0.1.0",
        'Abstract':'Abstract to this WPS',
    },
    'ServiceProvider': {
            'ProviderName' : "Your Company",
            'IndividualName':"Your Name",
            'PositionName':"Your Position",
            'Role':"your role",
            'DeliveryPoint': "Street",
            'City': "City",
            'PostalCode':"00000",
            'Country': "Your country",
            'ElectronicMailAddress':"your.email@address",
    },

    'OperationsMetadata': {
        'ServerAddress' : "http://localhost/cgi-bin/wps/wps.py",
    },
    'Keywords' : ['GRASS','GIS','WPS'],
}
```

In the `ServerSettings` section, the variables are set, which have impact on the whole server.

```python
ServerSettings = {
        # NOTE: You have to create this directory manually and set rights, so
        #       the program is able to store data in there
        'outputPath': '/var/www/wpsoutputs',

        #
        # 'outputUrl' - URL of the directory, where the outputs will be stored
        'outputUrl':  'http://192.168.1.31/wpsoutputs',

        #
        # tempPath - path to directory, where temporary data will be stored.
        # NOTE: the pywps has to have rights, to create directories and files
```

```
              #        in this directory
              'tempPath': '/tmp',

              #
              # maxOperations - maximum number of operations, which is allowed to low
              # on this server at ones
              # default = 1
              'maxOperations':1,

              #
              # maxSize: maximum input file size in bytes
              # NOTE: maximum file size is 5MB, no care, if this number is higher
              'maxSize':5242880, # 5 MB

              #
              # maxInputParamLength: maximal length of input values
              # NOTE: maximum length of input parameters is 256, no matter, how height
              #       is this number
              'maxInputParamLength':256,
}
```

4.2 etc/grass.py

This file servers for configuration of GRASS GIS environment (if your processes need one).
Everything is stored in grassenv structure.

```
grassenv = {
    # PATH in which your modules (processes) should be able the search.
    # Default value:
    'PATH': "/usr/local/grass-6.1.cvs/bin/:/usr/local/grass-6.1.cvs/scripts/:\
    /usr/bin/:/bin/:",

    # Add eventually some other path, in which should GRASS search for modules
    'GRASS_ADDON_PATH': "",

    # Version of GRASS, you are using
    'GRASS_VERSION': "6.1.cvs",

    # GRASS_PERL, where is your PERL bin installed
    'GRASS_PERL': "/usr/bin/perl",

    # GRASS_GUI should be always "text" unless you know, what you are doing
    'GRASS_GUI': "text",

    # GISBASE is place, where your GRASS installation is
    'GISBASE': "/usr/local/grass-6.1.cvs",
```

```
    # LD_LIBRARY_PATH
    'LD_LIBRARY_PATH':"/usr/local/grass-6.1.cvs/lib",

    # HOME has to be set
    'HOME':"/var/www",
}
```

5   Add your own processes

NOTE: This section has changed from previous stable 1.0.0 version. The processes, you
defined for 1.0.0 branch should work for 2.0.0 branch too.

All processes are stored in the `processes` directory. Put your file e.g. `myprocess.py` in
there. Several example processes are distributed along with PyWPS source code.

Process is python class derived from prepared `WPSProcess` class in `pywps.Wps` pack-
age. In it `__init__(self)` method, process metadata, inputs and outpus are defined and
in `execute(self)` method, own computation is performed.

It is possible also to add as many your functions, as you wish.

5.1   Process Initialization and Configuration

```
01 # importing necessary files
02 import pywps.Wps.WPSProcess
03
04 class Process(WPSProcess):
05     def __init__(self):
06         WPSProcess.__init__(self,
07             Identifier="ogr2ogr",
18             Title="ogr2ogr interface",
19             Abstract="Convert vector file to another format",
10             processVersion = "0.2",
11             statusSupported="true",
12             storeSupported="true")
```

We defined new process called `ogr2ogr`. The process is allowed to store it's output
data on the server (`storeSupported`) and it is also possible to run it in asynchronous mode
(`statusSupported`).

Eventually optional attributes can be found in the table 38 - "Parts of ExecuteResponse
data structure" in the WPS reference document[4]. It is also possible to redefine some variable
later, after initialization:

```
13
14         self.Title="ogr2ogr interface"
15
```

---

[4] http://www.opengeospatial.org/standards/requests/28

Metadata defition is stored in array `self.Metadata` in `__init__` method. You can add new Medatada using `self.AddMetadata()` method:

```
self.AddMetadata(Identifier="point",type="point",
                    textContent="Click in the map")
```

This code will produce in DescribeProcess responce document following element:

```
...
<ows:Metadata Identifier="point" type="point">
    Click in the map
</ows:Metadata>
...
```

5.1.1 Data Inputs

Data inputs are stored in `self.Inputs` array. To add inputs to your process, you should use methods defined in `WPSProcess` class.

Four types of data inputs are defined:

- Literal Input – Basic literal input – single number or text value

- ComplexValue Input – Mostly vector file embded in input XML request

- ComplexValueReference Input – URL to location, where the process is supposed to get the input data.

- BoundingBox Input – Coordinates for lower-left and upper-right corner.

ComplexValue and ComplexValueReference defined on the same way – PyWPS is able to guess, if the input data are reference (link) to some map or raw data directly.

LiteralInput Basic type of data input is `LiteralInput` type. To define LiteralInput the easy way, you should use `AddLiteralInput` method:

```
20
21          self.AddLiteralInput(Identifier="value",
                                 Title="Value to be added",
                                 type=type(0))
```

Above example will add new input with identifier `value` of type integer. Examples of other possibilities of LiteralInputs and resulting part of XML are folowing:

Example of any allowed input value (default)

```
self.AddLiteralInput(Identifier="someinput",
                    Title="Some Input",
                    allowedvalues='*')
```

```
...
  <Input>
```

9

```
        <ows:Identifier>someinput</ows:Identifier>
        <ows:Title>Some Input</ows:Title>
        <ows:Abstract/>
            <LiteralData>
                <SupportedUOMs defaultUOM="m">
                    <ows:UOM>m</ows:UOM>
                </SupportedUOMs>
                <ows:AnyValue/>
            </LiteralData>
        <MinimumOccurs>1</MinimumOccurs>
    </Input>
...
```

Example of specified list (with range) of allowed inputs Following example will define input with specified list of values: Only values 20, 30, everything between 40-100 and 110 will be accepted:

```
self.AddLiteralInput(Identifier="someinput",
                    Title="Some Input",
                    allowedvalues=[20,30,[40,100],110])
```

```
...
  <Input>
    <ows:Identifier>someinput</ows:Identifier>
    <ows:Title>Some Input</ows:Title>
    <ows:Abstract/>
    <LiteralData>
     <SupportedUOMs defaultUOM="m">
        <ows:UOM>m</ows:UOM>
        </SupportedUOMs>
        <AllowedValues>
            <Value>20</Value>
            <Value>30</Value>
            <Range>
                <MinimumValue>40</MinimumValue>
                <MaximumValue>100</MaximumValue>
            </Range>
            <Value>110</Value>
        </AllowedValues>
    </LiteralData>
    <MinimumOccurs>1</MinimumOccurs>
  </Input>
...
```

For further documentation, refere example processes distributed with the source code as well as `pydoc pywps/wps/process.py`. This help is also available in `process.html`[5] file

---

[5] Documentation to process.py module

distributed along with PyWPS source code.

ComplexInput   If the request comes as HTTP GET, it is assumed, that the input is only reference to some map. If it comes as HTTP POST, PyWPS tryes to guess, if the client is sending URL to source of the data or if the input data are part of input XML request (e.g. as GML file). So, you, as a process coder do not have to take care on this:

```
self.AddComplexInput(Indentifier="inputmap",
     Title="Input map, which should be processed",
     Formats=["text/xml","image/tiff"])
...
   <Input>
       <ows:Identifier>input</ows:Identifier>
       <ows:Title>Input raster map</ows:Title>
       <ows:Abstract/>
       <ComplexData defaultFormat="image/tiff">
           <SupportedComplexData>
               <Format>image/tiff</Format>
               <Format>text/xml</Format>
           </SupportedComplexData>
       </ComplexData>
       <MinimumOccurs>1</MinimumOccurs>
   </Input>
```

BoundingBox Input   With bounding box, you can define two coordinate pairs, if you have to.

```
self.AddBondingBoxInput(Identifier="bbox",
       Title="BBox input")
```

5.1.2   Data Outputs

Again four types of output are defined:

- Literal Output

- ComplexValue Output

- ComplexValue Reference

- BoundingBox Output

Data outputs can be defined on similar way, using similar methods:

LiteralOutput

```
self.AddLiteralOutput(Identifier="litoutput",
                  Title="Resulting output value")
```

11

```
...
  <Output>
    <ows:Identifier>litoutput</ows:Identifier>
    <ows:Title>Resulting output value</ows:Title>
    <ows:Abstract/>
    <LiteralOutput>
      <SupportedUOMs defaultUOM="m">
        <ows:UOM>m</ows:UOM>
      </SupportedUOMs>
    </LiteralOutput>
  </Output>
...
```

ComplexValue and ComplexValueReference Output   To the oposite of data Inputs, Outputs can distinguish between ComplexValue output and ComplexValueReference. ComplexValue is directly embed into the output XML document and ComplexValueReference is stored on the server and only URL pointing the the file is refering to it. In general, vector files in GML format can be easy embed to the output XML, TIFF raster files is better to leave on the server.

```
self.AddComplexReferenceOutput(Identifier="output",
                Title="Resulting output map",
                Formats=["image/tiff"])
```

```
...
  <Output>
    <ows:Identifier>output</ows:Identifier>
    <ows:Title>Resulting output map</ows:Title>
    <ows:Abstract/>
    <ComplexOutput defaultFormat="image/tiff">
      <SupportedComplexData>
        <Format>image/tiff</Format>
      </SupportedComplexData>
    </ComplexOutput>
  </Output>
...
```

BoundingBox Output   Beside LiteralValue and ComplexValue, BoundingBoxValue is also defined. The coordinates are stored in array of four members:

```
self.GetInputValue("bboxinput")
[0,0,100,100]
```

So on our `ogr2ogr` process, we have to define three types of input: `ComplexValue` of input vector file and EPSG codes of target and source files:

```
16      self.AddComplexInput(Identifier="inputmap",
17          Title ="Input vector file",
18          Abstract = "Input vector file to be converted",
19          Formats=["text/xml"])
20
21      self.AddLiteralInput(Identifier="sepsg",
22          Title="Source EPSG",
23          Abstract="Source EPSG code",
24          value=4326)
```

And we also define two outputs: ComplexValueReference and ComplexValue type.

```
25      self.AddComplexOutput(Identifier="outputmap",
26          Title ="Input vector file",
27          Abstract = "Input vector file to be converted",
28
29      self.LiteralOutput(Identifier="sepsg",
30          Title="Source EPSG",
31          Abstract="Source EPSG code",
32          value=4326)
```

5.2 Process Programming

The process must be defined in the `execute(self)` function. You can access the input values via `self.GetInputValue(Identifier)` method.

NOTE: Usage of the old method, accessing the values via `self.Inputs[index]['value']` or via `self.DataInputs` array is possible, but should not be used.

Also variable `self.grassenv` will be in your process at your service. This dictionary stores environment variables used by GRASS GIS, such se `LOCATION_NAME` or `MAPSET`.

Output values should be set using `self.SetOutputValue(Identifier, value)` method.

NOTE: Usage of the old methods of output values setting, directly to `self.Outputs[index]['value']` variable or to `self.DataOutputs['identifier']` dictionary, is possible, but should better not be used.

If you need to execute some shell command, you should use `self.Cmd(command,["string for standard input"])` instead of e.g. `os.system()` or `os.popen()` functions.

```
33
35      def execute(self):
36
37          #
38          # calculation
39          #
30          self.Cmd("""ogr2ogr -s_srs "+init=epsg:4326" -t_srs \
31          "+init=epsg:2065" %s output.file""" % (self.GetInputValue("inputmap")))
32          #
43          # setting results
```

```
44          #
45          self.SetOutputValue("outputmap","output.file")
46          self.SetOutputValue("sepsg","4326")
47
48          return
```

5.2.1 Error handling

At the end of the `execute` function, `None` value should be returned. Any other value means, that the calculation will be stopped and error report will be returned back to the client.

5.2.2 Using standard in- and output with external commands

The `self.Cmd()` accepts `input` parameter, wich is a text string, which is directred to standard input of the command:

```
result = self.Cmd(cmd="wc -c",
          input="calculate number of characters for this sentence")

# result[0].split()
```

`self.Cmd()` returns list of lines from the programms standard output to the process:

```
for line in self.Cmd("ls -l"):
    # do some operations of list of files
    pass
```

5.3 GRASS specific notes

Special class for GRASS GIS is defined too, which has functions and variables specific to this program. The process, in which should use GRASS modules should be defined as follows:

```
# importing necessary files
import pywps.Wps.GRASSWPSProcess

class Process(GRASSWPSProcess):
    def __init__(self):
        GRASSWPSProcess.__init__(self,
            Identifier="spearpath",
            Title="Spearfish path searching",
            Abstract="Find the shortest path on the roads map on Spearfish dataset",
            processVersion = "0.2",
            statusSupported="true",
            storeSupported="true",
            # grassLocation="/var/www/spearfish60/" # work on existing location)
```

By default, `self.grassLocation`[6] variable is set to `None`, which means, that temporary location will be created and after the calculation is done, it will be deleted again. You can set this while process initialization or later[7].

WPSProcess class provides special method `self.GCmd(command_string)`, which tryes to catch output from GRASS modules, especially progress information inidcated by percent done. Method `GCmd()` stores the output of GRASS modules to `self.status` variable, so if the process is running assynchronously, client application can track the progress of each module directly.

```python
def execute(self):
    """
    This function serves like simple GRASS - python script

    It returns None, if process succeed or String if process failed
    """
    self.GCmd("g.region -d")


    # v.net.path reads from standard input
    self.GCmd("v.net.path in=roads out=path","0 %s %s %s %s" % (self.GetInputValue('x1
            self.GetInputValue('y1'),
            self.GetInputValue('x2'),
            self.GetInputValue('y2')))

    self.GCmd("v.out.ogr format=GML input=path dsn=out.xml olayer=path.xml")

    if "out.xml" in os.listdir(os.curdir):
        shutil.copy("out.xml","out2.xml")
        self.SetOutputValue('outputReference',"out.xml")
        self.SetOutputValue('outputData',"out2.xml")
        return
    else:
        return "Ouput file not created!"
```

It is also possible to run GRASS modules using python's `os.system()` or `os.popen()` function. Before you do so, it is important to import the `os` python package (usually one of the first lines in the file). This approach might not be the best, but it is the simplest one. Feel free to use any other low-end functions.

Unfortunately, the GRASS modules are very verbose. Some messages are written to STDOUT, some to STDERR. The STDERR will be stored in the error file of your web server. But you have to "catch" the messages, sent to STDOUT. This can be done e.g. by using "1 > &2" statement (redirecting STDOUT to STDERR in shell):

```python
os.system("""
    echo "Rekni jim drazi, tatko, za to nic nedas."  >&2
""")
```

---

[6]See e.g. GRASS manual for details
[7]`self.grassLocation="/path/to/location"`

You can avoid this problem using formentioned `self.GCmd()` method.

6 Testing your new process

To test your PyWPS installation, you run it either as Webserver cgi-application or in the command line directly. It is always good to start with the command line test, so do not have to check `error.log` of the web server.

- GetCapabilities request (webserver)

```
./wps.py "service=wps&request=getcapabilities"
```

```
wget -nv -q -O - "http://localhost/cgi-bin/wps.py?\
    service=Wps&request=getcapabilities"
```

- DescribeProcess request:

```
./wps.py "version=0.4.0&service=Wps&request=DescribeProcess&\
    Identifier=your_process"
```

```
wget -nv -q -O - "http://localhost/cgi-bin/wps.py?\
    version=0.4.0&service=Wps&request=DescribeProcess&\
    Identifier=your_process"
```

- Execute request:

```
./wps.py "version=0.4.0&service=Wps&\
    request=Execute&Identifier=your_process&\
    datainputs=input1,value1,input2,value2"
```

```
wget -nv -q -O - "http://localhost/cgi-bin/wps.py?\
    version=0.4.0&service=Wps&\
    request=Execute&Identifier=your_process&\
    datainputs=input1,value1,input2,value2" \
```

7 Using PyWPS

7.1 Input

To get response from PyWPS you have to formulate appropriate query string first. You can use HTTP GET style or HTTP POST style.

HTTP GET style is standard URL, with all parameters in one line. You can not set any `ComplexValue` data in your process via HTTP GET. Example:

```
wget -nv -q -O - --post-data="version=0.4.0&service=Wps&\
    request=Execute&Identifier=your_process&\
    datainputs=input1,value1,input2,value2"\
    "http://localhost/cgi-bin/wps.py"
```

In HTTP POST style, you send one "request" parameter, which contains XML input. The XML file can contain also included ComplexValue data, e.g. GML file. Example:

```
wget --post-file=execute-post.txt \
        "http://localhost/pywps/wps.py" -O - -nv -q
```

The `execute-post.txt` file can look like follows:

```
<?xml version="1.0" encoding="utf-8"?>
<Execute service="WPS" version="0.4.0" store="false" status="false"
xmlns="http://www.opengeospatial.net/wps"
xmlns:ows="http://www.opengeospatial.net/ows"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengeospatial.net/wps/wpsDescribeProcess.xsd">
    <ows:Identifier>searchpath</ows:Identifier>
    <DataInputs>
        <Input>
            <ows:Identifier>streetmap</ows:Identifier>
            <ows:Title>The map</ows:Title>
            <ows:ComplexValue>
                <Value>
<ogr:FeatureCollection
     xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
     xsi:schemaLocation="http://ogr.maptools.org/ donut.xsd"
     xmlns:ogr="http://ogr.maptools.org/"
     xmlns:gml="http://www.opengis.net/gml">
  <gml:boundedBy>
    <gml:Box>
      <gml:coord><gml:X>4.263256414560601e-14</gml:X>
        <gml:Y>-70.71067811865474</gml:Y></gml:coord>
      <gml:coord><gml:X>141.4213562373095</gml:X>
      <gml:Y>70.71067811865474</gml:Y></gml:coord>
    </gml:Box>
  </gml:boundedBy>
  <gml:featureMember>
    <ogr:donut fid="F0">
      <ogr:geometryProperty><gml:LineString><gml:coordinates>
      70.710678118654755,70.710678118654741,0 141.42135623730951,0.0,
      0 70.710678118654741,-70.710678118654741,0 0.000000000000043,
      0.000000000000057,0 70.710678118654755,
      70.710678118654741,0</gml:coordinates>
      </gml:LineString></ogr:geometryProperty>
    </ogr:donut>
  </gml:featureMember>
  <gml:featureMember>
    <ogr:donut fid="F0">
      <ogr:geometryProperty><gml:LineString><gml:coordinates>50.000000000000014,
```

```
      0.000000000000021,0 71.213203435596427,-21.213203435596419,0
      92.426406871192853,0.0,0 71.213203435596427,21.213203435596423,0
      50.000000000000014,0.000000000000021,0</gml:coordinates>
      </gml:LineString></ogr:geometryProperty>
    </ogr:donut>
  </gml:featureMember>
</ogr:FeatureCollection>
                </Value>
            </ows:ComplexValue>
        </Input>

        <Input>
            <ows:Identifier>x1</ows:Identifier>
            <ows:LiteralValue>591679.31</ows:LiteralValue>
        </Input>
        <Input>
            <ows:Identifier>y1</ows:Identifier>
            <ows:LiteralValue>4927205.07</ows:LiteralValue>
        </Input>
        <Input>
            <ows:Identifier>x2</ows:Identifier>
            <ows:LiteralValue>608642.625</ows:LiteralValue>
        </Input>
        <Input>
            <ows:Identifier>y2</ows:Identifier>
            <ows:LiteralValue>4915876.31</ows:LiteralValue>
        </Input>
    </DataInputs>
</Execute>
```

You can see, that there are 4 inputs in this process:

1. ComplexValue GML File

2. x1 coordinate

3. y1 coordinate

4. x2 coordinate

5. y2 coordinate

7.2 Output

The output from PyWPS can be either XML file or results of processes directly. In default
configuration, no files are stored on the server, resulting values (maps) are returned to the
client. If you want to return XML file with outputs encoding, you have to enable it in you
process configuration with option `storeSupported`:

```
    self.storeSupported = "true"
```

And you have to call the PyWPS with "store=true" option:

```
version=0.4.0&service=Wps&request=Execute&Identifier=your_process&\
                datainputs=input1,value1,input2,value2&store=true
```

Or in XML input:

```
request=<?xml version="1.0" encoding="utf-8"?>
<Execute service="WPS" version="0.4.0" store="true" status="false"
xmlns="http://www.opengeospatial.net/wps"
xmlns:ows="http://www.opengeospatial.net/ows"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengeospatial.net/wps/wpsDescribeProcess.xsd">

...
```

This will cause PyWPS to look after `self.status` array in your process in form form

```
    self.status = ["Message", Percent_Done]
```

and generate XML file in statusLocation with this embed message. E.g.

```
    self.status = ["Generating raster map", 50]
```

or better

```
    self.SetStatus("Generarting raster map", 50_Done)
```

will become

```
...
    <Status>
            <ProcessStarted message="Generating raster map" percentCompleted="50"/>
    </Status>
...
```

A   Example process: `addvalue`

This sample process describes how to made your own WPS processes. Purpose of this process is:

- Download input raster map from some server
- Convert it to integer values

- Add input value to each raster cell

- Convert raster to vector

- Export raster to TIFF and vector to GML. Vector file will be embed ot output XML file.

```
"""

pywps process example:

addvalue: Adds some value to raster map
"""
# Author: Jachym Cepicky
#         http://les-ejk.cz
# Lince:        GNU/GPL
#
# Copyright (C) 2006 Jachym Cepicky

import os,time,string,sys,shutil
from pywps.Wps.process import GRASSWPSProcess

class Process (GRASSWPSProcess):
    #
    # Initialization
    #
    def __init__(self):
        GRASSWPSProcess.__init__(self,
                            Identifier="Addvalue",
                    Title="Add some value to input raster map",
                            processVersion = "0.2",
                            statusSupported="true",
                            storeSupported="true",
                            grassLocation = None)


        #
        # Inputs
        self.AddComplexInput(Identifier="input",
                            Title="Input raster map",
                            Formats=["image/tiff"])
        self.AddLiteralInput(Identifier="value",
                            Title="Value to be added",
                            type=type(0))


        #
        # Outputs
        self.AddComplexReferenceOutput(Identifier="output",
```

```python
                                 Title="Resulting output map",
                                 Formats=["image/tiff"])
#
# Execute part of the process
#
def execute(self):
    """
    This function
        1) Imports the raster map
        2) runs r.mapcalc out=in+value
        3) Exports the raster map
        4) returns the new file name or 'None' if something went wrong
    """


    # import of the data
    self.SetStatus("Importing data")
    if not self.GCmd("r.in.gdal -o in=%s out=input" %\
            (self.GetInputValue("input"))):
        return "Could not import raster file"
    self.SetStatus("Importing data",10)


    # compositing 3 bands to one raster file
    for gdalinfoln in os.popen("gdalinfo %s" %\
            (self.GetInputValue("input"))):
        if gdalinfoln.split()[0] == "Band" and gdalinfoln.split()[1] == "3":
            self.GCmd("""g.region rast=input.red """)
            self.GCmd("r.composite r=input.red b=input.blue g=input.green out=input")

    # region setting
    self.GCmd("""g.region rast=input""")

    # adding the value
    self.SetStatus("Adding new value to raster map",50)
    self.GCmd("r.mapcalc output='input+%f'" % float(self.GetInputValue('value')))

    # output
    self.SetStatus("Raster file export", 90)
    self.GCmd("r.out.gdal type=Int32 in=output out=%s" % "output.tif")

    # setting output values
    self.SetOutputValue("output","output.tif")
    if "output.tif" in os.listdir(os.curdir):
        return  # OK
    else:
        return "Output file not created!" # FAILED
    """
```

B   KVP request encoding of `addvalue`

This process can be lunched with URL:
http://localhost/cgi-bin/wps.py?service=wps&version=0.4.0&identifier=addvalue&request=execute&\
datainputs=input,http://localhost/data/raster.tif,value,250&status=true&store=true

C   XML request encoding `addvalue`

```
request=<?xml version='1.0' encoding='UTF-8' standalone='yes'?>
<Execute service='wps' version='0.4.0' store='true' status='false'
    xmlns="http://www.opengeospatial.net/wps"
    xmlns:ows="http://www.opengeospatial.net/ows">
<ows:Identifier>addvalue</ows:Identifier>
<DataInputs>
    <Input>
        <ows:Identifier>input</ows:Identifier>
        <ComplexValueReference reference='http://localhost/wps/data/soils.tif' />
    </Input>
    <Input>
        <ows:Identifier>value</ows:Identifier>
        <LiteralValue>250</LiteralValue>
    </Input>
    <!-- Input>
        <ows:Identifier>bbox</ows:Identifier>
        <BoundingBoxValue>
            <BoundingBox>
                <LowerCorner>-1 -1</LowerCorner>
                <UpperCorner>10 10</UpperCorner>
            </BoundingBox>
        </BoundingBoxValue>
    </Input -->
</DataInputs>
</Execute>
```

D   Licence of PyWPS

The GNU General Public License
Version 2, June 1991
Copyright © 1989, 1991 Free Software Foundation, Inc.

51 Franklin St, Fifth Floor, Boston, MA 02110-1301, USA

Everyone is permitted to copy and distribute verbatim copies of this license document, but changing it is not allowed.

Preamble

The licenses for most software are designed to take away your freedom to share and change it. By contrast, the GNU General Public License is intended to guarantee your freedom to share and change free software—to make sure the software is free for all its users. This General Public License applies to most of the Free Software Foundation's software and to any other program whose authors commit to using it. (Some other Free Software Foundation software is covered by the GNU Library General Public License instead.) You can apply it to your programs, too.

When we speak of free software, we are referring to freedom, not price. Our General Public Licenses are designed to make sure that you have the freedom to distribute copies of free software (and charge for this service if you wish), that you receive source code or can get it if you want it, that you can change the software or use pieces of it in new free programs; and that you know you can do these things.

To protect your rights, we need to make restrictions that forbid anyone to deny you these rights or to ask you to surrender the rights. These restrictions translate to certain responsibilities for you if you distribute copies of the software, or if you modify it.

For example, if you distribute copies of such a program, whether gratis or for a fee, you must give the recipients all the rights that you have. You must make sure that they, too, receive or can get the source code. And you must show them these terms so they know their rights.

We protect your rights with two steps: (1) copyright the software, and (2) offer you this license which gives you legal permission to copy, distribute and/or modify the software.

Also, for each author's protection and ours, we want to make certain that everyone understands that there is no warranty for this free software. If the software is modified by someone else and passed on, we want its recipients to know that what they have is not the original, so that any problems introduced by others will not reflect on the original authors' reputations.

Finally, any free program is threatened constantly by software patents. We wish to avoid the danger that redistributors of a free program will individually obtain patent licenses, in effect making the program proprietary. To prevent this, we have made it clear that any patent must be licensed for everyone's free use or not licensed at all.

The precise terms and conditions for copying, distribution and modification follow.

GNU General Public License

Terms and Conditions For Copying, Distribution and Modification

0. This License applies to any program or other work which contains a notice placed by the copyright holder saying it may be distributed under the terms of this General Public

License. The "Program", below, refers to any such program or work, and a "work based on the Program" means either the Program or any derivative work under copyright law: that is to say, a work containing the Program or a portion of it, either verbatim or with modifications and/or translated into another language. (Hereinafter, translation is included without limitation in the term "modification".) Each licensee is addressed as "you".

Activities other than copying, distribution and modification are not covered by this License; they are outside its scope. The act of running the Program is not restricted, and the output from the Program is covered only if its contents constitute a work based on the Program (independent of having been made by running the Program). Whether that is true depends on what the Program does.

1. You may copy and distribute verbatim copies of the Program's source code as you receive it, in any medium, provided that you conspicuously and appropriately publish on each copy an appropriate copyright notice and disclaimer of warranty; keep intact all the notices that refer to this License and to the absence of any warranty; and give any other recipients of the Program a copy of this License along with the Program.

   You may charge a fee for the physical act of transferring a copy, and you may at your option offer warranty protection in exchange for a fee.

2. You may modify your copy or copies of the Program or any portion of it, thus forming a work based on the Program, and copy and distribute such modifications or work under the terms of Section 1 above, provided that you also meet all of these conditions:

   (a) You must cause the modified files to carry prominent notices stating that you changed the files and the date of any change.

   (b) You must cause any work that you distribute or publish, that in whole or in part contains or is derived from the Program or any part thereof, to be licensed as a whole at no charge to all third parties under the terms of this License.

   (c) If the modified program normally reads commands interactively when run, you must cause it, when started running for such interactive use in the most ordinary way, to print or display an announcement including an appropriate copyright notice and a notice that there is no warranty (or else, saying that you provide a warranty) and that users may redistribute the program under these conditions, and telling the user how to view a copy of this License. (Exception: if the Program itself is interactive but does not normally print such an announcement, your work based on the Program is not required to print an announcement.)

   These requirements apply to the modified work as a whole. If identifiable sections of that work are not derived from the Program, and can be reasonably considered independent and separate works in themselves, then this License, and its terms, do not apply to those sections when you distribute them as separate works. But when you distribute the same sections as part of a whole which is a work based on the Program, the distribution of the whole must be on the terms of this License, whose permissions for other licensees extend to the entire whole, and thus to each and every part regardless of who wrote it.

Thus, it is not the intent of this section to claim rights or contest your rights to work written entirely by you; rather, the intent is to exercise the right to control the distribution of derivative or collective works based on the Program.

In addition, mere aggregation of another work not based on the Program with the Program (or with a work based on the Program) on a volume of a storage or distribution medium does not bring the other work under the scope of this License.

3. You may copy and distribute the Program (or a work based on it, under Section 2) in object code or executable form under the terms of Sections 1 and 2 above provided that you also do one of the following:

   (a) Accompany it with the complete corresponding machine-readable source code, which must be distributed under the terms of Sections 1 and 2 above on a medium customarily used for software interchange; or,

   (b) Accompany it with a written offer, valid for at least three years, to give any third party, for a charge no more than your cost of physically performing source distribution, a complete machine-readable copy of the corresponding source code, to be distributed under the terms of Sections 1 and 2 above on a medium customarily used for software interchange; or,

   (c) Accompany it with the information you received as to the offer to distribute corresponding source code. (This alternative is allowed only for noncommercial distribution and only if you received the program in object code or executable form with such an offer, in accord with Subsection b above.)

The source code for a work means the preferred form of the work for making modifications to it. For an executable work, complete source code means all the source code for all modules it contains, plus any associated interface definition files, plus the scripts used to control compilation and installation of the executable. However, as a special exception, the source code distributed need not include anything that is normally distributed (in either source or binary form) with the major components (compiler, kernel, and so on) of the operating system on which the executable runs, unless that component itself accompanies the executable.

If distribution of executable or object code is made by offering access to copy from a designated place, then offering equivalent access to copy the source code from the same place counts as distribution of the source code, even though third parties are not compelled to copy the source along with the object code.

4. You may not copy, modify, sublicense, or distribute the Program except as expressly provided under this License. Any attempt otherwise to copy, modify, sublicense or distribute the Program is void, and will automatically terminate your rights under this License. However, parties who have received copies, or rights, from you under this License will not have their licenses terminated so long as such parties remain in full compliance.

5. You are not required to accept this License, since you have not signed it. However, nothing else grants you permission to modify or distribute the Program or its derivative works. These actions are prohibited by law if you do not accept this License. Therefore,

by modifying or distributing the Program (or any work based on the Program), you indicate your acceptance of this License to do so, and all its terms and conditions for copying, distributing or modifying the Program or works based on it.

6. Each time you redistribute the Program (or any work based on the Program), the recipient automatically receives a license from the original licensor to copy, distribute or modify the Program subject to these terms and conditions. You may not impose any further restrictions on the recipients' exercise of the rights granted herein. You are not responsible for enforcing compliance by third parties to this License.

7. If, as a consequence of a court judgment or allegation of patent infringement or for any other reason (not limited to patent issues), conditions are imposed on you (whether by court order, agreement or otherwise) that contradict the conditions of this License, they do not excuse you from the conditions of this License. If you cannot distribute so as to satisfy simultaneously your obligations under this License and any other pertinent obligations, then as a consequence you may not distribute the Program at all. For example, if a patent license would not permit royalty-free redistribution of the Program by all those who receive copies directly or indirectly through you, then the only way you could satisfy both it and this License would be to refrain entirely from distribution of the Program.

   If any portion of this section is held invalid or unenforceable under any particular circumstance, the balance of the section is intended to apply and the section as a whole is intended to apply in other circumstances.

   It is not the purpose of this section to induce you to infringe any patents or other property right claims or to contest validity of any such claims; this section has the sole purpose of protecting the integrity of the free software distribution system, which is implemented by public license practices. Many people have made generous contributions to the wide range of software distributed through that system in reliance on consistent application of that system; it is up to the author/donor to decide if he or she is willing to distribute software through any other system and a licensee cannot impose that choice.

   This section is intended to make thoroughly clear what is believed to be a consequence of the rest of this License.

8. If the distribution and/or use of the Program is restricted in certain countries either by patents or by copyrighted interfaces, the original copyright holder who places the Program under this License may add an explicit geographical distribution limitation excluding those countries, so that distribution is permitted only in or among countries not thus excluded. In such case, this License incorporates the limitation as if written in the body of this License.

9. The Free Software Foundation may publish revised and/or new versions of the General Public License from time to time. Such new versions will be similar in spirit to the present version, but may differ in detail to address new problems or concerns.

   Each version is given a distinguishing version number. If the Program specifies a version number of this License which applies to it and "any later version", you have the option of following the terms and conditions either of that version or of any later version published by the Free Software Foundation. If the Program does not specify a version

number of this License, you may choose any version ever published by the Free Software Foundation.

10. If you wish to incorporate parts of the Program into other free programs whose distribution conditions are different, write to the author to ask for permission. For software which is copyrighted by the Free Software Foundation, write to the Free Software Foundation; we sometimes make exceptions for this. Our decision will be guided by the two goals of preserving the free status of all derivatives of our free software and of promoting the sharing and reuse of software generally.

No Warranty

11. Because the program is licensed free of charge, there is no warranty for the program, to the extent permitted by applicable law. Except when otherwise stated in writing the copyright holders and/or other parties provide the program "as is" without warranty of any kind, either expressed or implied, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose. The entire risk as to the quality and performance of the program is with you. Should the program prove defective, you assume the cost of all necessary servicing, repair or correction.

12. In no event unless required by applicable law or agreed to in writing will any copyright holder, or any other party who may modify and/or redistribute the program as permitted above, be liable to you for damages, including any general, special, incidental or consequential damages arising out of the use or inability to use the program (including but not limited to loss of data or data being rendered inaccurate or losses sustained by you or third parties or a failure of the program to operate with any other programs), even if such holder or other party has been advised of the possibility of such damages.

End of Terms and Conditions

E   Licence of this document

GNU Free Documentation License
Version 1.2, November 2002
Copyright ©2000,2001,2002 Free Software Foundation, Inc.

51 Franklin St, Fifth Floor, Boston, MA 02110-1301 USA

Everyone is permitted to copy and distribute verbatim copies of this license document, but changing it is not allowed.

Preamble

The purpose of this License is to make a manual, textbook, or other functional and useful document "free" in the sense of freedom: to assure everyone the effective freedom to copy and redistribute it, with or without modifying it, either commercially or noncommercially. Secondarily, this License preserves for the author and publisher a way to get credit for their work, while not being considered responsible for modifications made by others.

This License is a kind of "copyleft", which means that derivative works of the document must themselves be free in the same sense. It complements the GNU General Public License, which is a copyleft license designed for free software.

We have designed this License in order to use it for manuals for free software, because free software needs free documentation: a free program should come with manuals providing the same freedoms that the software does. But this License is not limited to software manuals; it can be used for any textual work, regardless of subject matter or whether it is published as a printed book. We recommend this License principally for works whose purpose is instruction or reference.

1. APPLICABILITY AND DEFINITIONS

This License applies to any manual or other work, in any medium, that contains a notice placed by the copyright holder saying it can be distributed under the terms of this License. Such a notice grants a world-wide, royalty-free license, unlimited in duration, to use that work under the conditions stated herein. The **"Document"**, below, refers to any such manual or work. Any member of the public is a licensee, and is addressed as **"you"**. You accept the license if you copy, modify or distribute the work in a way requiring permission under copyright law.

A **"Modified Version"** of the Document means any work containing the Document or a portion of it, either copied verbatim, or with modifications and/or translated into another language.

A **"Secondary Section"** is a named appendix or a front-matter section of the Document that deals exclusively with the relationship of the publishers or authors of the Document to the Document's overall subject (or to related matters) and contains nothing that could fall directly within that overall subject. (Thus, if the Document is in part a textbook of mathematics, a Secondary Section may not explain any mathematics.) The relationship could be a matter of historical connection with the subject or with related matters, or of legal, commercial, philosophical, ethical or political position regarding them.

The **"Invariant Sections"** are certain Secondary Sections whose titles are designated, as being those of Invariant Sections, in the notice that says that the Document is released under this License. If a section does not fit the above definition of Secondary then it is not allowed to be designated as Invariant. The Document may contain zero Invariant Sections. If the Document does not identify any Invariant Sections then there are none.

The **"Cover Texts"** are certain short passages of text that are listed, as Front-Cover Texts or Back-Cover Texts, in the notice that says that the Document is released under this License. A Front-Cover Text may be at most 5 words, and a Back-Cover Text may be at most 25 words.

A **"Transparent"** copy of the Document means a machine-readable copy, represented in a format whose specification is available to the general public, that is suitable for revising the document straightforwardly with generic text editors or (for images composed of pixels) generic paint programs or (for drawings) some widely available drawing editor, and that is

suitable for input to text formatters or for automatic translation to a variety of formats suitable for input to text formatters. A copy made in an otherwise Transparent file format whose markup, or absence of markup, has been arranged to thwart or discourage subsequent modification by readers is not Transparent. An image format is not Transparent if used for any substantial amount of text. A copy that is not "Transparent" is called **"Opaque"**.

Examples of suitable formats for Transparent copies include plain ASCII without markup, Texinfo input format, LaTeX input format, SGML or XML using a publicly available DTD, and standard-conforming simple HTML, PostScript or PDF designed for human modification. Examples of transparent image formats include PNG, XCF and JPG. Opaque formats include proprietary formats that can be read and edited only by proprietary word processors, SGML or XML for which the DTD and/or processing tools are not generally available, and the machine-generated HTML, PostScript or PDF produced by some word processors for output purposes only.

The **"Title Page"** means, for a printed book, the title page itself, plus such following pages as are needed to hold, legibly, the material this License requires to appear in the title page. For works in formats which do not have any title page as such, "Title Page" means the text near the most prominent appearance of the work's title, preceding the beginning of the body of the text.

A section **"Entitled XYZ"** means a named subunit of the Document whose title either is precisely XYZ or contains XYZ in parentheses following text that translates XYZ in another language. (Here XYZ stands for a specific section name mentioned below, such as **"Acknowledgements"**, **"Dedications"**, **"Endorsements"**, or **"History"**.) To **"Preserve the Title"** of such a section when you modify the Document means that it remains a section "Entitled XYZ" according to this definition.

The Document may include Warranty Disclaimers next to the notice which states that this License applies to the Document. These Warranty Disclaimers are considered to be included by reference in this License, but only as regards disclaiming warranties: any other implication that these Warranty Disclaimers may have is void and has no effect on the meaning of this License.

2. VERBATIM COPYING

You may copy and distribute the Document in any medium, either commercially or non-commercially, provided that this License, the copyright notices, and the license notice saying this License applies to the Document are reproduced in all copies, and that you add no other conditions whatsoever to those of this License. You may not use technical measures to obstruct or control the reading or further copying of the copies you make or distribute. However, you may accept compensation in exchange for copies. If you distribute a large enough number of copies you must also follow the conditions in section 3.

You may also lend copies, under the same conditions stated above, and you may publicly display copies.

3. COPYING IN QUANTITY

If you publish printed copies (or copies in media that commonly have printed covers) of the Document, numbering more than 100, and the Document's license notice requires Cover Texts, you must enclose the copies in covers that carry, clearly and legibly, all these Cover

Texts: Front-Cover Texts on the front cover, and Back-Cover Texts on the back cover. Both covers must also clearly and legibly identify you as the publisher of these copies. The front cover must present the full title with all words of the title equally prominent and visible. You may add other material on the covers in addition. Copying with changes limited to the covers, as long as they preserve the title of the Document and satisfy these conditions, can be treated as verbatim copying in other respects.

If the required texts for either cover are too voluminous to fit legibly, you should put the first ones listed (as many as fit reasonably) on the actual cover, and continue the rest onto adjacent pages.

If you publish or distribute Opaque copies of the Document numbering more than 100, you must either include a machine-readable Transparent copy along with each Opaque copy, or state in or with each Opaque copy a computer-network location from which the general network-using public has access to download using public-standard network protocols a complete Transparent copy of the Document, free of added material. If you use the latter option, you must take reasonably prudent steps, when you begin distribution of Opaque copies in quantity, to ensure that this Transparent copy will remain thus accessible at the stated location until at least one year after the last time you distribute an Opaque copy (directly or through your agents or retailers) of that edition to the public.

It is requested, but not required, that you contact the authors of the Document well before redistributing any large number of copies, to give them a chance to provide you with an updated version of the Document.

4. MODIFICATIONS

You may copy and distribute a Modified Version of the Document under the conditions of sections 2 and 3 above, provided that you release the Modified Version under precisely this License, with the Modified Version filling the role of the Document, thus licensing distribution and modification of the Modified Version to whoever possesses a copy of it. In addition, you must do these things in the Modified Version:

A. Use in the Title Page (and on the covers, if any) a title distinct from that of the Document, and from those of previous versions (which should, if there were any, be listed in the History section of the Document). You may use the same title as a previous version if the original publisher of that version gives permission.

B. List on the Title Page, as authors, one or more persons or entities responsible for authorship of the modifications in the Modified Version, together with at least five of the principal authors of the Document (all of its principal authors, if it has fewer than five), unless they release you from this requirement.

C. State on the Title page the name of the publisher of the Modified Version, as the publisher.

D. Preserve all the copyright notices of the Document.

E. Add an appropriate copyright notice for your modifications adjacent to the other copyright notices.

F. Include, immediately after the copyright notices, a license notice giving the public permission to use the Modified Version under the terms of this License, in the form shown in the Addendum below.

G. Preserve in that license notice the full lists of Invariant Sections and required Cover Texts given in the Document's license notice.

H. Include an unaltered copy of this License.

I. Preserve the section Entitled "History", Preserve its Title, and add to it an item stating at least the title, year, new authors, and publisher of the Modified Version as given on the Title Page. If there is no section Entitled "History" in the Document, create one stating the title, year, authors, and publisher of the Document as given on its Title Page, then add an item describing the Modified Version as stated in the previous sentence.

J. Preserve the network location, if any, given in the Document for public access to a Transparent copy of the Document, and likewise the network locations given in the Document for previous versions it was based on. These may be placed in the "History" section. You may omit a network location for a work that was published at least four years before the Document itself, or if the original publisher of the version it refers to gives permission.

K. For any section Entitled "Acknowledgements" or "Dedications", Preserve the Title of the section, and preserve in the section all the substance and tone of each of the contributor acknowledgements and/or dedications given therein.

L. Preserve all the Invariant Sections of the Document, unaltered in their text and in their titles. Section numbers or the equivalent are not considered part of the section titles.

M. Delete any section Entitled "Endorsements". Such a section may not be included in the Modified Version.

N. Do not retitle any existing section to be Entitled "Endorsements" or to conflict in title with any Invariant Section.

O. Preserve any Warranty Disclaimers.

If the Modified Version includes new front-matter sections or appendices that qualify as Secondary Sections and contain no material copied from the Document, you may at your option designate some or all of these sections as invariant. To do this, add their titles to the list of Invariant Sections in the Modified Version's license notice. These titles must be distinct from any other section titles.

You may add a section Entitled "Endorsements", provided it contains nothing but endorsements of your Modified Version by various parties–for example, statements of peer review or that the text has been approved by an organization as the authoritative definition of a standard.

You may add a passage of up to five words as a Front-Cover Text, and a passage of up to 25 words as a Back-Cover Text, to the end of the list of Cover Texts in the Modified Version. Only one passage of Front-Cover Text and one of Back-Cover Text may be added by (or through arrangements made by) any one entity. If the Document already includes a cover

text for the same cover, previously added by you or by arrangement made by the same entity you are acting on behalf of, you may not add another; but you may replace the old one, on explicit permission from the previous publisher that added the old one.

The author(s) and publisher(s) of the Document do not by this License give permission to use their names for publicity for or to assert or imply endorsement of any Modified Version.

5. COMBINING DOCUMENTS

You may combine the Document with other documents released under this License, under the terms defined in section 4 above for modified versions, provided that you include in the combination all of the Invariant Sections of all of the original documents, unmodified, and list them all as Invariant Sections of your combined work in its license notice, and that you preserve all their Warranty Disclaimers.

The combined work need only contain one copy of this License, and multiple identical Invariant Sections may be replaced with a single copy. If there are multiple Invariant Sections with the same name but different contents, make the title of each such section unique by adding at the end of it, in parentheses, the name of the original author or publisher of that section if known, or else a unique number. Make the same adjustment to the section titles in the list of Invariant Sections in the license notice of the combined work.

In the combination, you must combine any sections Entitled "History" in the various original documents, forming one section Entitled "History"; likewise combine any sections Entitled "Acknowledgements", and any sections Entitled "Dedications". You must delete all sections Entitled "Endorsements".

6. COLLECTIONS OF DOCUMENTS

You may make a collection consisting of the Document and other documents released under this License, and replace the individual copies of this License in the various documents with a single copy that is included in the collection, provided that you follow the rules of this License for verbatim copying of each of the documents in all other respects.

You may extract a single document from such a collection, and distribute it individually under this License, provided you insert a copy of this License into the extracted document, and follow this License in all other respects regarding verbatim copying of that document.

7. AGGREGATION WITH INDEPENDENT WORKS

A compilation of the Document or its derivatives with other separate and independent documents or works, in or on a volume of a storage or distribution medium, is called an "aggregate" if the copyright resulting from the compilation is not used to limit the legal rights of the compilation's users beyond what the individual works permit. When the Document is included in an aggregate, this License does not apply to the other works in the aggregate which are not themselves derivative works of the Document.

If the Cover Text requirement of section 3 is applicable to these copies of the Document, then if the Document is less than one half of the entire aggregate, the Document's Cover Texts may be placed on covers that bracket the Document within the aggregate, or the electronic equivalent of covers if the Document is in electronic form. Otherwise they must appear on printed covers that bracket the whole aggregate.

8. TRANSLATION

Translation is considered a kind of modification, so you may distribute translations of the Document under the terms of section 4. Replacing Invariant Sections with translations requires special permission from their copyright holders, but you may include translations of some or all Invariant Sections in addition to the original versions of these Invariant Sections. You may include a translation of this License, and all the license notices in the Document, and any Warranty Disclaimers, provided that you also include the original English version of this License and the original versions of those notices and disclaimers. In case of a disagreement between the translation and the original version of this License or a notice or disclaimer, the original version will prevail.

If a section in the Document is Entitled "Acknowledgements", "Dedications", or "History", the requirement (section 4) to Preserve its Title (section 1) will typically require changing the actual title.

9. TERMINATION

You may not copy, modify, sublicense, or distribute the Document except as expressly provided for under this License. Any other attempt to copy, modify, sublicense or distribute the Document is void, and will automatically terminate your rights under this License. However, parties who have received copies, or rights, from you under this License will not have their licenses terminated so long as such parties remain in full compliance.

10. FUTURE REVISIONS OF THIS LICENSE

The Free Software Foundation may publish new, revised versions of the GNU Free Documentation License from time to time. Such new versions will be similar in spirit to the present version, but may differ in detail to address new problems or concerns. See http://www.gnu.org/copyleft/.

Each version of the License is given a distinguishing version number. If the Document specifies that a particular numbered version of this License "or any later version" applies to it, you have the option of following the terms and conditions either of that specified version or of any later version that has been published (not as a draft) by the Free Software Foundation. If the Document does not specify a version number of this License, you may choose any version ever published (not as a draft) by the Free Software Foundation.