Labwork Remote Sensing

How to use and to extract information from remote sensing images for land management ?

Mathieu Fauvel

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Contents

1 Introduction

1.1 Objectives of the labworks

The main objective of these labworks is to

be able to use and to extract information from remote sensing images for land management.

Information can be any knowledge of a given landscape (landcover, land-use, humidity, ...) that is used to understand the configuration and/or the evolution of landscape.

In terms of *competences*, you should be able to master at the end of the sessions the items listed in tables 1, 2, 3, 4 and 5. Each of them is organized as a set of tasks that should be mastered progressively.

Table 1: Choose images with properties adapted to your problematic.

Remember	Properties of remote sensing images.
Understand	Physical meaning of each sampling of a given image.
Apply	Open and visualize a remote sensing image, extract its properties.
Analyze	Describe a remote sensing image. Recognize specific object.
Evaluate	Choose the good image adapted to what you are looking for.
Create	Create a set of properties needed for your problematic.

Table 2: Compute and use spectral indices.

Remember	Definition of spectral indices in general and of the NDVI in particular.
Understand	What (and why) does the NDVI emphasize.
Apply	Perform the computation of spectral indices.
Analyze	Analysis of the vegetation cover using NDVI.
Evaluate	Choose the right spectral index.
Create	Select from the literature a set of possible indices.

Table 3: Define, identify and analyze radiometric behavior.

Remember	Spectral signature for *vegetation* and *water* object.
Understand	Histogram of images.
Apply	Compute an histogram.
Analyze	Extract radiometric properties of some classes.
Evaluate	Choose relevant spectral bands and/or indices for the segmentation of several classes.
Create	Perform a segmentation using radiometric statistics on one or many spectral variables and/or indices.

Table 4: Perform and discuss pixel-wise classification of image

Remember	Definition of pixel-wise supervised classification.
Understand	The parameters of several classification algorithm, how the spatial sampling of the ground truth data influence the training and validation steps.
Apply	Classification algorithms.
Analyze	Interpret the confusion matrix and the thematic map, the quality of a ground truth.
Evaluate	Compare two classification maps/results.
Create	Choose the most appropriate classifier for one given application, build good ground truth data.

Table 5: Define and implement a processing chain

Remember	How to combine several bands, apply a given function to train a classifier or to predict a thematic map.
Understand	The different inputs and outputs of `OTB` functions, how to use their corresponding documentation.
Apply	Apply a set of different functions in a pipeline.
Analyze	Define the different processing needed to perform a given task.
Evaluate	Evaluate the accuracy of the given processing, check for errors.
Create	Shell scripts that automatize most the processes, in order to apply them on a large set of images or to apply several embedded processes.

Table 6: Create and implement an algorithm in Qgis

Remember	How to implement your algorithm in `Qgis`.
Understand	The different inputs and outputs of `Qgis processing` GUI, and how to use their corresponding documentation.
Apply	Create an algorithm in python working on its own (outside of `Qgis`).
Analyze	Define the different constraints of your plugin (libraries, integer or float images, same projection...)
Evaluate	Check for errors and/or alert user within `Qgis` using alert or log messages.
Create	A `Qgis` plugin having algorithms available in the processing toolbox in order to combine them to other `Qgis` algorithms.

1.2 Remote sensing software

In these labworks, free and open sources softwares will be used to visualize remote sensing images, to process them and to implement processing chains. In the following, each software/tools will be briefly described. Interested reader can find more information on the associated website. In particular, the installation process is not detailed. However, they can be freely download and installed on many operating systems from their official website.

Students from the MASTER SIGMA - Specialization *Agrogéomatique* (A. Greco) has made a youtube channel to help you in using/installing the different softwares:

`https://www.youtube.com/channel/UCcxj3jqQVu3w4y1397l_jKQ`

1.2.1 Orfeo ToolBox (OTB)

OTB is a C++ library for remote sensing images processing. It has been developed by the CNES (French space agency) during the ORFEO program to *prepare, accompany and promote the use and the exploitation of the images derived from Pleiades satellites (PHR)*. Processing tools from OTB are appropriated to big images. When possible, processes are paralyzed and tiled automatically for users. Many applications derived from OTB and called *OTB-Applications* are directly usable for most of the common processing, they are described here. For advanced users, it is possible to develop program based on the OTB library (not considered in these labworks).

Monteverdi2 is *graphical user interface* that allows users to visualize and process remote sensing images with *OTB-Applications*. It is also developed by the CNES during the ORFEO program.

1.2.2 QGIS

QGIS is a *Geographic Information System* (GIS). It is used to open, visualize and process digital map. It includes several spatial analysis tools working mainly on vector data. QGIS can be extended by several plugin (`https://plugins.qgis.org/`) and modules, such as the OTB applications.

1.2.3 Geospatial Data Abstraction Library (GDAL)

GDAL is a library for the processing of raster and vector data. Similar to OTB, it has several applications that can be used directly. For advanced users, it is possible to develop program based on the GDAL library (not considered in these labworks).

1.2.4 Python

Pyhton is a programming language. It has several programming capabilities, such as *object-oriented*, *functional programming*, *dynamic type* and *memory management* that make it widely used in several applications:

- Web and internet development,
- Scientific and numeric computing,
- Software development.

It has a large number of available packages that can be used in many applications. For instance, it is possible to call *OTB-Applications* or *GDAL* from Python.

Table 7: Sequences

Sequences	Type	Volume	Topics
[2017-09-20 Wed 13:30]–[2017-09-20 Wed 17:30]	CTD	04:00:00	Visualization of remote sensing data + Spectral indices
[2017-09-22 Fri 13:30]–[2017-09-22 Fri 17:30]	CTD	04:00:00	Segmentation of RS images + Floods detection
[2017-09-25 Mon 13:30]–[2017-09-25 Mon 17:30]	CTD	04:00:00	Classification of RS images
[2017-09-27 Wed 13:30]–[2017-09-27 Wed 15:30]	CTD	02:00:00	Classification of RS images
[2017-09-27 Wed 15:30]–[2017-09-27 Wed 17:30]	Project	02:00:00	Spatial distribution of pixels
[2017-09-29 Fri 13:30]–[2017-09-29 Fri 16:30]	CTD	03:00:00	Dynamic Habitat Index
[2017-10-02 Mon 08:00]–[2017-10-02 Mon 10:00]	EXAM	02:00:00	EXAM Groupe 1 & 2
Total		21:00:00	

Table 8: Sequences

Sequences	Type	Volume	Topics
[2017-10-02 Mon 10:00]–[2017-10-02 Mon 12:00]	CTD	02:00:00	Introduction to Scipy: array manipulation
[2017-10-09 Mon 13:30]–[2017-10-09 Mon 17:30]	CTD	04:00:00	Template filters 1/2
[2017-10-11 Wed 13:30]–[2017-10-11 Wed 15:30]	CTD	02:00:00	Template filters 2/2 + GDAL manipulation 1/2
[2017-10-16 Mon 13:30]–[2017-10-16 Mon 17:30]	CTD	04:00:00	GDAL manipulation 2/2 + Historical Maps 1/2
[2017-10-18 Wed 13:30]–[2017-10-18 Wed 15:30]	Projet	02:00:00	Historical Maps 2/2
[2017-10-23 Mon 13:30]–[2017-10-23 Mon 17:30]	CTD	04:00:00	Linking Qgis to Python - Your first processing plugin
[2017-11-09 Thu 08:00]–[2017-11-09 Thu 10:00]	EXAM	02:00:00	EXAM Groupe 1 & 2
Total		20:00:00	

1.3 Sequences

1.3.1 Remote Sensing - Introduction

1.3.2 Remote Sensing - Advanced

1.4 During the labworks

For the *presential* sequences, you won't have to do any report. But you will have to write your personal material on remote sensing. You are encouraged to write it progressively during the sessions. **It will be the only document approved for the exam** (with those on moodle). The length of each sequence should let you enough time to write the report.

For the *non presential* sequences, you will be asked to write a document that describe briefly the results and how you obtained them. Discussion between all groups will be done during the next session.

2 Data sets

2.1 Pleiades images

These images were acquired over the Fabas forest in 2013. Images were acquired the *<2013-10-12 Sat>* and the *<2013-12-10 Tue>*, respectively. A true color composition is given in Figure 1.

Images are stored using the GeoTIFF format. It is an extended version of the TIFF format, which allows to embed geospatial information within the file. GeoTIFF can be read by most of the remote sensing and GIS software. Table 9 gives the band order of the data.

2.2 Formosat 2 Satellite image time series

This time series was acquired in 2012 over the region of *Saint Lys*. It consists in a set of Formosat-2 images along the year 2012. Figure 3 provide information about the acquisition date and the Figure 2

Figure 1: Fabas image acquired the *[2013-10-12 Sat]*.

Table 9: Bands and channels information for the Pleiades images

Band	Channel
1	Red
2	Green
3	Blue
4	Infra-red

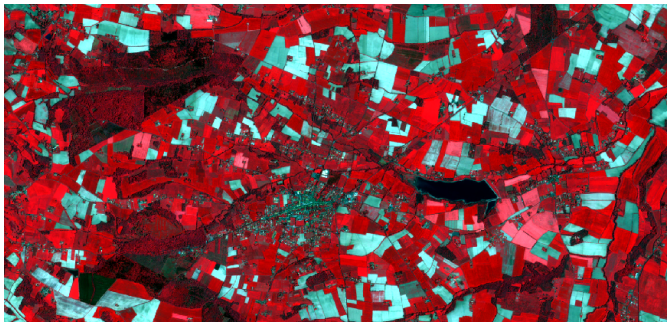


Figure 2: Formosat 2 image acquired the *[2012-05-03 Thu]*.

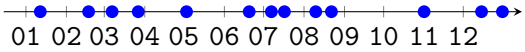


Figure 3: Acquisition dates for the SITS 2012.

shows a false colors composition for the date *[2012-05-03 Thu]*. Table 10 gives the band order of the data.

Table 10: Bands and channels information for the Formosat images

Band	Channel
1	Blue
2	Green
3	Red
4	Infra-red

2.3 Historical Maps

The figure 4 shows an historical map. This is a scan performed by the IGN of an old manually drawn map.

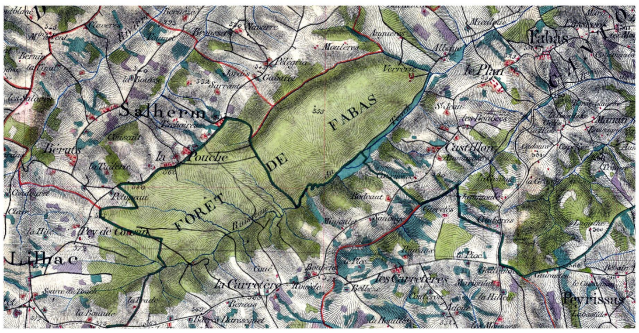


Figure 4: Historical Maps

3 Visualization of remote sensing data

3.1 Vizualization of remote sensing image

The vizualisation of remote sensing images can be done either with Monteverdi2 or QGIS[1]. QGIS might be a more efficient when it comes to visualize several images, or for the vizualisation of vector layers. It will be used in these labworks.

Most of the information regarding the vizualisation of raster data with QGIS can be found online `http://docs.qgis.org/2.14/en/docs/user_manual/working_with_raster/raster_properties.html`.

More generally, to use raster data with QGIS is described here `http://docs.qgis.org/2.14/en/docs/user_manual/working_with_raster/index.html`.

In this labwork, a few properties will be reviewed and you are encouraged to check (at least) the given references.

[1]The library `matplotlib` of python is not adapted to visualize remote sensing image and should be avoided.

3.1.1 Vizualization of grayscale image

Open the image *fabas_10_12_2013.tif* with QGIS. The default view is a colour composition, with the bands/channels association given in Table 11. To start easy, we just open one band at a time: right click on the name of the opened image in the *Layer* pane et select *Properties*. Then select the tab *Style* and *Band rendering*. In the *render type*, select *Singleband gray* and the band you want to display.

You surely have to do *Contrast enhancement*. Check the doc for that.

Table 11: Bands and channels default association in QGIS (if there is not a set of specified spectral bands in the metadata).

Band	Channel
1	Red
2	Green
3	Blue

Work 3.1:

1. Visualize each spectral band of the data, and look at the differences in terms of graylevel between spectral bands.
2. Zoom in/out: use the mousse's wheel to zoom into the image. What do you observe ?

3.1.2 Vizualization of colour image

Now you can visualize a colour images, by selecting three spectral bands among those available from the data. Again, *Contrast enhancement* should be done.

Work 3.2:

1. Do a "true colours" and "false colours" compositions and compare what is easily seen on each of them.
2. Get spectral values for several pixels corresponding to different materials (water, grassland, forest and bare soil). For that, use the tool *Identify features*, see http://docs.qgis.org/2.14/en/docs/user_manual/introduction/general_tools.html for detail.
3. Fill the *collaborative spreadsheet* with your pixel values:
   - https://framacalc.org/fauvel_rs_water
   - https://framacalc.org/fauvel_rs_grassland
   - https://framacalc.org/fauvel_rs_forest
   - https://framacalc.org/fauvel_rs_baresoil

3.2 Get data information

Before opening a remote sensing data, it is possible to get some information about its properties. For instance, using `gdalinfo` it is possible to extract several information. It can be used as

```
gdalinfo fabas_10_12_2013.tif
```

Help on the function can be obtained using the command alone or by doing :

```
man gdalinfo
```

Equivalently, it is possible to get the same information using the function `otbcli_ReadImageInfo` from the *OTB-Applications*:

```
otbcli_ReadImageInfo -in fabas_10_12_2013.tif
```

Work 3.3:

On the *Fabas* data set, get the following information.

1. Number of lines, columns and bands,
2. Size of each pixel,
3. Numerical types for coding pixel values,
4. Position of the upper left pixel,
5. Projection.

4 Spectral indices: *Normalized Difference Vegetation Index*

Among the available radiometric indices, only the NDVI is considered in this labwork. NDVI is widely used for vegetation monitoring because it can be related to chlorophyll content and photosynthesis.

Work 4.1:

1. Compute the NDVI for each *Fabas* image. You can compute the NDVI using several ways, using either *OTB-Applications* or the *Raster Calculator* http://docs.qgis.org/2.14/en/docs/user_manual/working_with_raster/raster_analysis.html#raster-calculator. For a per band analysis, both methods are equivalent. Using QGIS provides the Graphical user interface, which can be convenient for processing few images, while *OTB-Applications* allow to process large number of images using *shell* programming.

   Using the raster calculator, the following formula can be used (for the Fabas image):

   ```
   ("fabas_12_10_2013@4"-"fabas_12_10_2013@1")/("fabas_12_10_2013@4"+"fabas_12_10_2013@1")
   ```

   Using the *OTB-Applications*, it is possible to use `otbcli_BandMath`. The syntax is similar, since we need to define the image, the bands used and the expression of our processing:

   ```
   otbcli_BandMath -il fabas_12_10_2013.tif -out ndvi_fabas.tif -exp
    ↪  "(im1b4-im1b1)/(im1b4+im1b1)"
   ```

2. Compare the NDVI obtained for each date and explain your results.

5 Segmentation of remote sensing images

5.1 Radiometric analysis

Work 5.1:

For the NDVI of the image *[2013-10-12 Sat]*, do

1. Look at the histogram and identify the local maxima. For each local maximum, try to identify the corresponding pixels in the image,
2. Keep track of the characteristics of each identified maximum (position and width).

5.2 Segmentation of 1D histogram

In this part, the extraction of image's pixels sharing the same *radiometric behavior* is considered. The analysis of the histogram is used to estimate this *behavior*. When only one material is segmented, the output is a binary image (image with value `0` or `1`), where pixels having value `1` are from the same material. Figure 5 gives an example of such outputs. When several material are considered, the output is an images with integer values (`1`, `2`, `3` ...), depending on the number of materials.

Figure 5: Binary image for Water.

A usual work-flow is proposed in this part. First, QGIS is used to analyze the data and set-up the processing (parameters *etc*). Then, the *OTB-Applications* are used to automatize the processing.

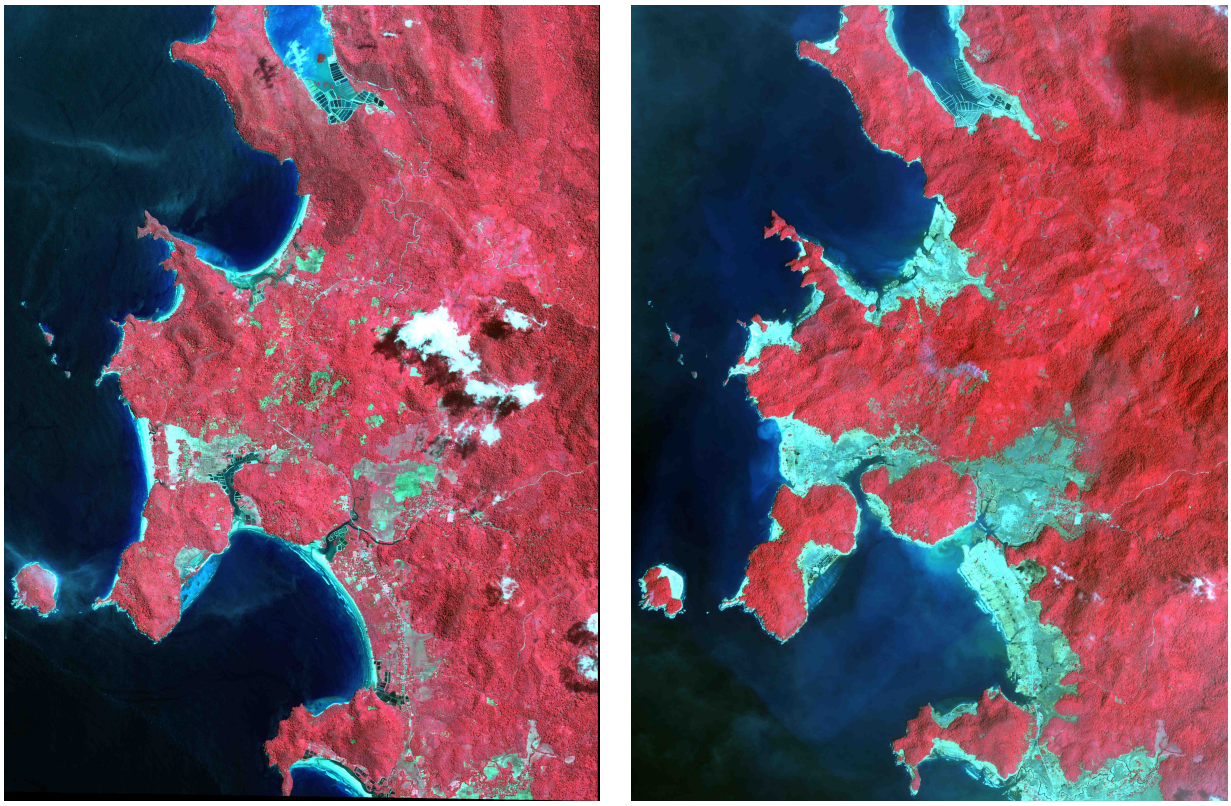
Work 5.2:

Segment the identified material on the NDVI. For that, you need to define interval of pixel values for which a specific action is done (*e.g.*, set the value to 0 or 1). Implement the processing using the `BandMath` application.

5.3 Graphical Modeler

For the segmentation of the NVDI, two processings are required

1. First, the computation of the NDVI from the original image,



(a) (b)

Figure 6: False colours images of Lhonga Leupung area (a) before and (b) after flooding.

2. Second, the definition of the interval of values to extract the relevant pixels.

With the graphical modeler, it is possible to define your workflow, to automatize complex tasks. Take a look at http://docs.qgis.org/2.14/en/docs/user_manual/processing/modeler.html.

Work 5.3:

Define your model to perform the segmentation of intro three classes of the NDVI.

6 Change detection: *Detection of floods*

Change detection in remote sensing consists in detecting differences between two images, or a set of images. It can be used to detect changes in vegetation properties or in land cover. It is also used in disaster management, to detect impacted areas. In this labwork, we are dealing with floods. In Figure 6 is shown two quickbird images, before and after a flooding. The objective is to identify the impacted area to provide a map of these zones

Work 6.1:

1. Characterize the impacted zones in terms of radiometric behavior, *i.e.*, what is the variation in terms of spectral values. And why ?
2. Define the processing chain to extract these areas.
3. Implement the processing chain with the graphical modeler.
4. Optional: Implement the same processing chain with shell scripts, see 10.1.

Figure 7: Google view of the impacted area. The red square represents the area of Figure 6.

7 Classification of remote sensing images

7.1 Introduction

The aim of this labwork is to perform the classification of remote sensing images using supervised algorithms. The principle is the same than segmentation. But now the gray level intervals are not defined manually and the definition of a radiometric behavior is not limited to a rectangular area in the spectral domain. Furthermore, since all the computation are done by supervised algorithms, it is possible to use more information than one or two bands and the full multispectral image can be use. In fact, more than one image can be used. In this work, the two *Fabas* images will be classified: first separately and then conjointly.

The OTB proposes various classifiers, each one having different characteristics. In order to train (or learn) the classifier, some labeled pixels should be provided. It is possible to construct the ground-truth (set of labeled pixels) in different ways:

- Using GIS layer and extract the relevant information at the pixel level.
- Do field survey and use GPS to identify pixels.
- Do photo-interpretation when possible.

In this works, the ground-truth is provided as a vector file, see 8. Five classes are considered, they are given in Table 12.

During this labwork, it is proposed to compare in terms of classification accuracy and processing time some of the classifiers proposed in OTB and all the combination of input data, *i.e.*:

- K-nn, Bayes, SVM and Random Forest.

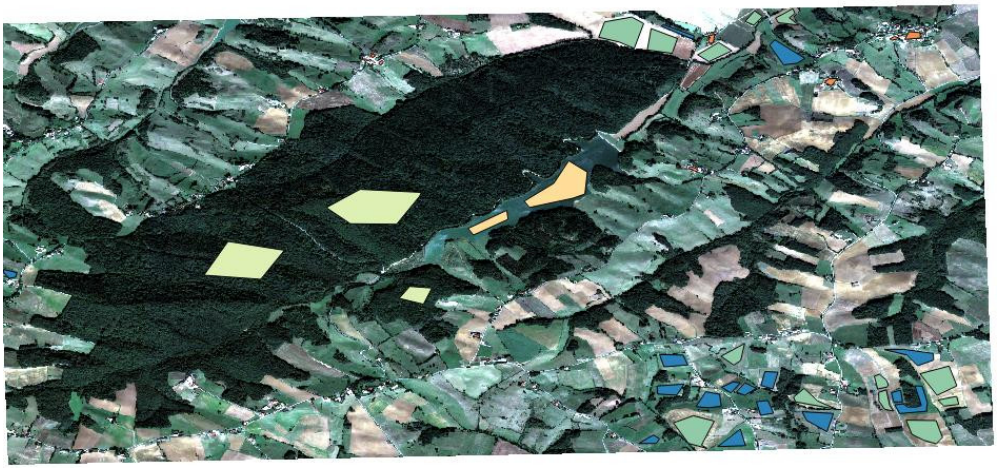


Figure 8: Ground truth for the *Fabas* image.

Table 12: Classes of interest. Numbers corresponding to the attribute in the GIS file is also given.

Classes	Sparse vegetation	Bare soil	Woody vegetation	Water	Built up
Attribute	1	2	3	4	5

- The ground-truth being composed of pixels from one date, and two *concatenated* dates.

7.2 Getting started with OTB

There are several steps to do a classification.

1. *Learn the classifier*: It is done with `TrainImagesClassifier`. It takes as inputs, the (set of) remote sensing image(s), the ground-truth (in vector format), and some parameters of the method. To learn the classifier, only the pixels inside the ground-truth are used. After this step, a *model* that contains the parameters is saved. If asked, a confusion matrix is computed.

2. *Classify the image*: Once the classifier is learned, it is possible to apply the model to all the pixels of the image. It can be done with `ImageClassifier`.

3. Compute the accuracy of the thematic map according to some groundthruth. **This groundthruth should not be spatially correlated with the one used for training**. The confusion matrix can be computed using the function `ComputeConfusionMatrix`.

Work 7.1:

This should be done for one image and one classifier only.

1. Learn the model,
2. Apply the model to classify the entire image,
3. Compute the confusion matrix and save it in a *csv* file.
4. Open the CSV using a spreadsheet. From the confusion matrix, compute the following indices:
   - Global accuracy,
   - Producer accuracy,
   - User accuracy.

7.3 Automatize the process with scripts (shell, python or the Graphical modeler)

It is possible to run directly the *OTB-Applications* from the the command line. This way, it is possible to run several operations on one data set or on several data sets automatically. A brief introduction to command line tools is given in Appendix 10.1.

The three previous *OTB-Applications* are available from the command line interface (CLI), same name with the prefix `otbcli_` :

- `otbcli_TrainImagesClassifier`,
- `otbcli_ImageClassifier`,
- `otbcli_ComputeConfusionMatrix`.

The same inputs than in QGIS should be provided (*raster and vector file, algorithm parameters ...*). For instance, if you are in the directory where the data are, learning the KNN classifier with default parameters do the following, classifying the whole image and computing the confusion matrix reduce to

```
otbcli_TrainImagesClassifier \
    -io.il fabas_12_10_2013.tif \
    -io.vd train_fabas.shp \
    -classifier knn \
    -io.out model.mod
otbcli_ImageClassifier \
    -in fabas_12_10_2013.tif \
    -model model.mod \
    -out fabas_classif.tif
otbcli_ComputeConfusionMatrix \
    -in fabas_classif.tif \
    -out matconf.csv \
    -ref vector \
    -ref.vector.in valid_fabas.shp
```

This is nothing else than what you provide in QGIS ! In the following, we are going to combine Python scripts and the OTB Applications to define our processing chain. Two python modules will be use: os and glob. These modules are very convenient to manage files, folder and to launch applications. Also, we are going to benefit Python abilities to process strings.

Let's start with an example, to run the first application

```
# Load the module
import os

# Launch the application
os.system('otbcli_TrainImagesClassifier -io.il fabas_12_10_2013.tif -io.vd train_fabas.shp -classifier
 ↪  knn -io.out model.mod')
os.system('otbcli_ImageClassifier -in fabas_12_10_2013.tif -model model.mod -out fabas_classif.tif')
os.system('otbcli_ComputeConfusionMatrix -in fabas_classif.tif -out matconf.csv -ref vector
 ↪  -ref.vector.in valid_fabas.shp')
```

or equivalently:

```
# Load the module
import os

# Define processing
train = 'otbcli_TrainImagesClassifier -io.il fabas_12_10_2013.tif -io.vd train_fabas.shp -classifier knn
 ↪  -io.out model.mod'
classify = 'otbcli_ImageClassifier -in fabas_12_10_2013.tif -model model.mod -out fabas_classif.tif'
validate = 'otbcli_ComputeConfusionMatrix -in fabas_classif.tif -out matconf.csv -ref vector
 ↪  -ref.vector.in valid_fabas.shp'

# Launch the application
os.system(train)
os.system(classify)
os.system(validate)
```

Additional usefull references are given section 10.2, take the time to read them.

Alternatively, it is possible to use the *batch processing interface* provided by the graphical modeler of QGIS. It allows the batch execution of a model over several inputs. Take a look at the following link for further details:

https://docs.qgis.org/2.14/en/docs/user_manual/processing/batch.html?highlight=batch

According to your preference, use one of these techniques to do the following tasks:

Work 7.2:

1. Write the script/modeler to learn the model for all the classification methods and with each date. Each time extract the confusion matrix and compute the global accuracy and the class average accuracy.
2. Report the results on the *collaborative spreadsheet*: https://framacalc.org/fauvel_res_classification
3. For the best method in terms of classification accuracy, discuss about the errors obtained with the confusion matrix.
4. Classify the whole image and compare by visual inspection the errors with what you have inferred from the confusion matrix.

7.4 Influence of the spatial distribution of the learning samples

In order to evaluate the influence of the validation samples, you will investigate several reference layers to compute the confusion matrix. Since OTB only select a few samples from all the available one (can be controlled with the options `samples.mt` and `samples.mv`), we need to repeat the experiment several times, to avoid bias.

```
import scipy as sp
import glob
# get all the csv files that match the pattern and order the list in increasing order
NAMES_TRAIN,NAMES_VALID = glob.glob('confu_train_*.csv'),glob.glob('confu_valid_*.csv')
NAMES_TRAIN.sort()
NAMES_VALID.sort()

oa_train,oa_valid = [],[]

for name_train,name_valid in zip(NAMES_TRAIN,NAMES_VALID):
    temp = sp.genfromtxt(name_train,delimiter=',',skip_header=2) # read the file, skip the two first
     ↪  lines (of comments)
    oa = 100*sp.diag(temp).sum()/temp.sum() # Compute the overall accuracy
    oa_train.append(oa) # add the values to the list
    temp = sp.genfromtxt(name_valid,delimiter=',',skip_header=2)
    oa = 100*sp.diag(temp).sum()/temp.sum()
    oa_valid.append(oa)

# Compute mean accuracy and standard deviation and save the results
res = [[sp.mean(oa_train),sp.std(oa_train)],[sp.mean(oa_valid),sp.std(oa_valid)]]
sp.savetxt('acc.csv',res,delimiter=',',fmt='%1.3f')
```

Figure 9: Sample code to process a set of `csv` files.

Select one classifier for all the experiments. You are encouraged to define a python/shell script or a modeler.

Work 7.3:

Repeat 20 times the following test:

1. Learn with *train_fabas* and compute the confusion matrix with *train_fabas*. Save the confusion matrix for each repetition.
2. Learn with *train_fabas* and compute the confusion matrix with *valid_fabas*. Save the confusion matrix for each repetition.
3. Compute the average global accuracy and the mean class accuracy and their standard deviation. *You can check the figure 9 to do it automatically.*

Discuss about the results.

8 Dynamic Habitat Index

8.1 Introduction

In this labworks, we are going to compute several indices of habitat dynamic's in order to define several ecozones. It is bases on the following paper:

> Nicholas C. Coops, Michael A. Wulder, Dennis C. Duro, Tian Han, Sandra Berry, The development of a Canadian dynamic habitat index using multi-temporal satellite estimates of canopy light absorbance, Ecological Indicators, Volume 8, Issue 5, September 2008, Pages 754-766, ISSN 1470-160X, http://dx.doi.org/10.1016/j.ecolind.2008.01.007. (http://www.sciencedirect.com/science/article/pii/S1470160X08000071)

These indicators underly vegetation dynamic, they are usually computed in the *fraction of photosynthetically active radiation (fPAR)* absorbed by the vegetation. However these data are not available. So in this lab, the NDVI will be used. The data is described in 2.2.

Work 8.1:

The first (easy) part is to convert NDVI values to fPAR like values. Since fPAR is a fraction, its values are between 0 and 1. You have to convert the interval range of NDVI to 0 and 1 using a simple linear function: $f(x) = ax + b$. You have to find a and b !

$$\begin{aligned} f : [-1, 1] &\rightarrow [0, 1] \\ x &\mapsto f(x) = ax + b \end{aligned}$$

8.2 Construction of the SITS

Before analyzing the SITS, you need to built it.

Work 8.2:

1. Compute the NDVI for each date,
2. Convert to fPAR-like values,
3. Concatenate all the dates,
4. Using QGIS, plot the temporal profile for several objects.

8.3 Computation of the dynamic indices

The second part of the labwork concern the computation of the dynamic indices. Let us note the vector of fPAR values of pixel i $\mathbf{x}_i = [\mathbf{x}_i(t_1), \ldots, \mathbf{x}_i(t_d)]$. Three indices have been defined:

1. The cumulative annual greenness,

$$CG = \sum_{j=1}^{d} \mathbf{x}_i(t_j)$$

1. The annual minimum cover,

$$MC = \min_j \left[\mathbf{x}_i(t_1), \ldots, \mathbf{x}_i(t_j), \ldots, \mathbf{x}_i(t_d)\right]$$

1. The greenness coefficient of variation.

$$GCV = \frac{\sigma_{\mathbf{x}_i}}{\mu_{\mathbf{x}_i}}$$

Work 8.3:

1. Write the python scripts to compute all indices.
2. Concatenate all the indices into one multiband image.

```python
def TheFilter(imin,p1=p1,p2=p2, ...):
    """This function apply the filter TheFilter on image imin with
    parameters p1, p2, ...p2

    Input:
    -----
    imin = image to be processed, Scipy 2D-Array
    p1 = parameter 1 of the filter, default value p1
    p2 = parameter 1 of the filter, default value p2

    Output:
    ------
    imout = filtered image, Scipy 2D-Array, not necessraly of the same
    type as imin, depending of the filter
    """

    ## Some processing

    ## Other processing

    return imout
```

Figure 10: Skeleton of the filter

8.4 Characterization of ecozones

Perform a segmentation of the SITS using the three indices as input values. A primarily study suggests the number of ecozones is 4 for this area. Look at the function `otbcli_KMeansClassification` to perform the automatic segmentation of you data.

Work 8.4:

1. Performs the segmentation with 4 classes and save the values of the estimated centroid.
2. Extract the values of the centroid and interpret their values in terms of habitat.
3. Do a visual validation of your results on the thematic map.

9 Python for Remote Sensing data analysis

9.1 Template filters

9.1.1 Introduction

In this labwork, images will be provided under the `Scipy` format. How to open remote sensing images with `GDAL` will be addressed later. To load an image using `Scipy` just do

```python
import scipy as sp
image = sp.load('dataname.npy')
```

In the following, you will have to write python functions (mainly image filters). In figure 10 is provided a skeleton of such function, using simple docstring convention. You are highly encouraged to put comment in your code !

Work 9.1:

1. With template filters, there are a list of pre-processing that needs to be done every time. Find them out. (Here we do not care about *edge effect*: pixels at the border of the image will not be processed)
   - check of inputs,
   - initialization of the output image,
   - ...
2. Complete the skeleton to have a ready-to-use function, where you will just have to implement the operation in the neighborhood. Few lines of codes to scan all the pixel of the images.

9.1.2 Template filters function

Using the previously defined skeleton, implement the following filter: `max`, `min`, `median`, `mean`. You can use methods of scipy array class describe below:
https://docs.scipy.org/doc/numpy/reference/generated/numpy.amax.html
https://docs.scipy.org/doc/numpy/reference/generated/numpy.amin.html
https://docs.scipy.org/doc/numpy/reference/generated/numpy.mean.html
https://docs.scipy.org/doc/numpy/reference/generated/numpy.median.html

Work 9.2:

1. Start with a simple template, a fixed size moving window of 3×3 pixels. Write your function.
2. Modify your function to include an input parameter that control the size of the moving window (only consider odd size).
3. When your function is working correctly, try to improve the processing time. You can use the module `time`, see https://pymotw.com/2/time/.
4. Apply your function on the Ikonos images and try to remove the noise.

9.1.3 To go further

- Extend your function for multidimensional images.
- Provide function with a rectangular template (with odd size).
- For the mean filter, add a new parameter that define the number of *cycle*, i.e., the number of times the filter is applied iteratively on the image.
- Implement the following filters and try to explain what are they action.
  - `max(im)-im`
  - `im-min(im)`
  - `max(im)-min(im)`

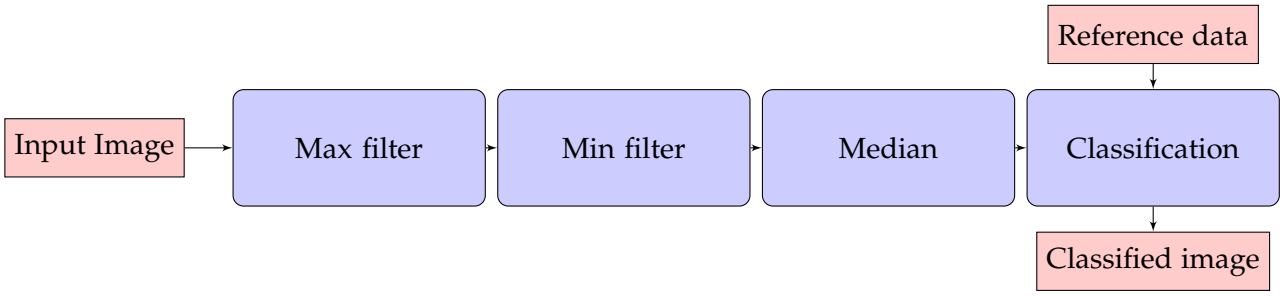


Figure 11: Processing chain.

9.2 Historical map processing

This section is dedicated to the implementation of the filtering part of the following paper

> P-A Herrault, D Sheeren, M Fauvel, and M Paegelow. Automatic extraction of forests from historical maps based on unsupervised classification in the cielab color space. In Geographic Information Science at the Heart of Europe, pages 95–112. Springer International Publishing, 2013.

It concerns the filtering of historical maps, see 2.3 to see the data to be processed. The filtering consists in the application of the consecutive filters, on every bands of the color image:

1. Local max filter,
2. Local min filter,
3. Local median filter,

as illustrated in the (simplified) processing chain shown in 4. You should write a script that takes as arguments:

- The name of the image,
- the name of the output image,
- the size of the min/max filter,
- the size of the median filter,

an, off course, do the right processing.

Work 9.3:

1. Write the main steps of the filtering:
   a) Load the image
   b) Filter the image
   c) Write the results
2. Add the necessary machinery to make a python application
   a) Add command line arguments parser (see 10.2.4)
   b) Make you function executable

```
chmod +x yourfunction.py
```

3. Play with it to find the best couple of parameters to remove black line in the historical map.

9.3 QGIS Script

QGIS offers facilities to call python scripts directly from QGIS. We are going to see how it is possible to use our previous script, which slight modifications, directly in QGIS. Doing this has two main advantages:

1. Let QGIS does the job for the selection and the visualization of the images,
2. Use QGIS pre-defined function to handle arguments of our functions.

9.3.1 Install *Script Runner*

Script Runner is a QGIS plugin that allows to integrate python script very easily: you don't need to worry about linking your script to QGIS, it is done automatically. To install it, just do *Extensions* -> *Manage and Install Plugins* and select the plugin.

Once the plugin is installed in QGIS, you can import your scripts.

9.3.2 Creating script for QGIS and *Script Runner*

Your script needs slight modification in order to be imported in *Script Runner*.

1. Add the following modules to interact with QGIS:

```
from PyQt4.QtCore import *
from PyQt4.QtGui import *
from qgis.core import *
from qgis.gui import *
```

2. First you should define a function `run_script(iface)` where the processing is done. `iface` is a python object that gives access to several QGIS objects and classes. It is used to communicate with QGIS. You can also add arguments to the function: when the script is run, a window will be automatically created to ask you to fill the value of each parameter. For instance, if you need to define bands corresponding to infrared and red and the name of the output file:

```
def run_script(iface,IR,R,data_name)
```

3. The second modification need is to get the name of the data of current layer in QGIS. It is done using `iface` object:

```
layer = iface.activeLayer() # Get the current layer
name = layer.dataProvider().dataSourceUri() # Get the path of the layer
```

Then, once the processed file has been saved on the hard drive, it is possible to load directly the file into QGIS, again by using `iface`:

```
raster_lyr = iface.addRasterLayer('name_of_the_data','name_of_the_layer')
```

4. The last modification is not mandatory, but it will simplify the use of your script. Don't use `import`, but directly put all your additional functions before the `run_script` function.

Work 9.4:

Make your script and use it from QGIS.

9.4 A plugin to make accessible an algorithm in the Qgis Processing toolbox

Thanks to the Processing ToolBox developped by Victor Olaya, it is now possible to use your algorithm with others QGIS algorithms. The plugin automatically creates a Graphical User Interface (GUI), hence there are some guidelines to follow in order to be compatible with QGIS.

9.4.1 Plugin Builder in QGIS

Plugin Builder is a plugin in QGIS which allows you to automatize the creation of plugins by giving him some information (name of your processing plugin, author name, bug tracker url...). Some of them are mandatory because the aim of Plugin Builder is to share your creation with every user of Qgis. Once you fulfill all these informations, you will find your plugin in the same folder as others already installed plugins :

```
# ~/ refer to your user /home/USER folder
cd ~/.qgis2/python/plugins/YourPluginClassName
```

9.4.2 Implement your code

After the creation of your plugin, you should have your folder organize as follow:

```
ls #list of files and folders in YourPluginClassName
help          metadata.txt               pluginModule.py   README.txt
i18n          pb_tool.cfg                plugin_upload.py  scripts
__init__.py   pluginModule_algorithm.py  pylintrc          test
Makefile      pluginModule_provider.py   README.html
```

As there are not so much documentation available for using GUI of Processing ToolBox, the easiest way to find the functions and classes to call is by watching the code : Inputs(parameters), Outputs.

1. Setting inputs

   By default, the *pluginModule_algorithm.py* is the one that contains lines used to create the standard GUI and to run the script. This file imports different classes :

```
from PyQt4.QtCore import QSettings
from qgis.core import QgsVectorFileWriter

from processing.core.GeoAlgorithm import GeoAlgorithm
from processing.core.parameters import ParameterVector
from processing.core.outputs import OutputVector
from processing.tools import dataobjects, vector
```

   For our work (Making the Historical Map Filter process in Qgis Algorithm), we need two different inputs :

   - Raster image
   - Integer values (closing filter size, median filter size and median filter iteration)

   When looking in Inputs (parameters) in *processing* code, we see different inputs corresponding to each of our need :

```
class ParameterNumber(Parameter) # line 302
# ...
# then
# ...
class ParameterRaster(Parameter) # line 364
```

   Now to import these two classes, simply call in your `pluginModule_algorithm.py`:

```
from processing.core.parameters import ParameterRaster,ParameterNumber
```

   Parameters can have differents arguments (only accept shapefiles with polygon type not points, etc...). When looking in the parameter file (__init__ of ParameterNumber)

```
# __init__ of ParameterNumber class
def __init__(self, name='', description='', minValue=None, maxValue=None,
                default=None, optional=False, metadata={})
```

   Once you found arguments in the *__init__* of your parameter class, add this asked variable in the *defineCharacteristics* function of your *pluginModule_algorithm.py* :

```
def defineCharacteristics(self):
# add input of Number type
self.addParameter(
  #...
  ParameterNumber(
    self.CLOSING_SIZE,
    self.tr('Window size of closing filter'),
    minValue=3,
    default=5))
```

   Just don't forget to define your variable *CLOSING_SIZE* at the beginning of your pluginClassAlgorithm(GeoAlgorithm) :

```
# add input of Number type
class pluginClassAlgorithm(GeoAlgorithm):
  #...
  CLOSING_SIZE = 'Size of closing filter window'
  # And so on (INPUT_RASTER...)
```

2. Setting outputs The Historical Map filtering process outputs one raster. When looking in Outputs file in the processing code, we see every output compatible with the Processing GUI.

```
class OutputRaster(Output)
```

To import this Output settings, simply import this class :

```
from processing.core.outputs import OutputRaster
```

Then add this argument in the *defineCharacteristics* function :

```
def defineCharacteristics(self):
  #...
  self.addOutput(
    OutputRaster(
    self.OUTPUT_RASTER,
    self.tr('Output raster (filtered image)')))
```

As for the inputs, don't forget to define the variable in your class root :

```
# add input of Number type
class pluginClassAlgorithm(GeoAlgorithm):
  CLOSING_SIZE = 'CLOSING_SIZE'
  OUTPUT_RASTER = 'OUTPUT_RASTER'
  # And so on (INPUT_RASTER...)
```

3. Connect the processing code to your function

Once inputs and outputs are correctly defined, you need to use them to run your class or function. To get the value the user choose for inputs and outputs parameters, the GeoAlgorithm class class has a function named *getParameterValue*. Simply use it to give it in your function arguments.

```
def processAlgorithm(self, progress):
    """Here is where the processing itself takes place."""

    INPUT_RASTER = self.getParameterValue(self.INPUT_RASTER)
    #...
    OUTPUT_RASTER = self.getOutputValue(self.OUTPUT_RASTER)

    #classify
    historicalMapProcess(INPUT_RASTER,OUTPUT_RASTER,*args)
```

9.4.3 Debug and/or talk with the final user

It's hard to debug a code inside of Qgis. That's why you have to make sure your code perfectly works outside of Qgis before implementing it inside this tool.

1. Log a message

   In the qgis.core folder, you can import QgsMessageLog which allows you to write some lines in the log panel below the map in the main window of Qgis.

```
from qgis.core import QgsMessageLog
```

   Then, when you need to verify some arguments, or to write something useful for the user or for you, simply write :

```
QgsMessageLog.logMessage("Input raster is "+str(INPUT_RASTER))
```

2. Alert the user The log is a good tool to store some informations (for debugging it is a great option), but to alert the user if there's a problem, it's not the best choice. Qgis let you the possibility to write a message over the map with a colorful background : the user can't ignore it !

```
from qgis.utils import iface
```

   The message must first retrieve the interface currently used (iface), the push his message over the map :

```
iface.messageBar().pushMessage("Error", "I'm just a student, I do mistakes, lot of mistakes!")
```

   You can set the duration of the message (it will automatically hide after) and the altert color (from light to critical)

```
from qgis.gui import QgsMessageBar

# TOUT VA BIEN ! Green color background
iface.messageBar().pushMessage("Well done !", "My algorithm works perfectly
 ↪  !",level=QgsMessageBar.SUCCESS,duration=3)

# OH OH... There's a bug, isn't it ? Light blue background.
iface.messageBar().pushMessage("Ohoh...", "It's not just works as I
 ↪  expected...",level=QgsMessageBar.INFO,duration=5)

# CATASTROPHE ! Red background, it's horryfing !
iface.messageBar().pushMessage("Error", "There's a serious problem over here... Maybe I should
 ↪  rewrite all the code...",level=QgsMessageBar.CRITICAL,duration=10)
```

Work 9.5:

Make your own Qgis plugin and use it from the *Processing Toolbox*. Tips : You can customize your plugin by choosing a new icon.

10 Appendix

10.1 Short introduction to shell

This section provides an introduction to *shell* programming and *shell scripts*. A script is a set of commands, which allows to write a processing chain for a given image, or to apply one processing to a set

of images. Of course, mixing these two situations is possible. You can find more information easily on the web, a good starting point can be the Wikibook.

Shell is a programming language that is available on all GNU/Linux distributions. It can be used directly from the prompt (interactive mode), or by writing a file with a set of commands to be run. This file should start with the line

```
#!/bin/bash
```

In the following, it is assumed that we are working on the file `script.sh`. To insert comment inside the script, the symbol `#` has to be used.

```
# This is a comment
```

With Linux, a file can be *writable*, *readable* and/or *executable*. To be run as a script, it should be at least *executable* by the OS. It can be by done by running the following command:

```
chmod +x script.sh
```

To run it, just do

```
./script.sh
```

10.1.1 Basic commands

- **cd**: Change directory. To enter a directory, do `cd Name_Of_Directory`.
- **ls**: List all the file in the current directory.
- **pwd**: Return the name of the current directory.
- **cp**: Copy a file/directory, for instance `cp A B`.
- **mv**: Move a file to another, for instance `mv A B`.
- **mkdir**: Create a directory, `mkdir Name_Of_Directory`.

For instance, to get all the `tif` files in the current folder:

```
ls *tif
fabas_10_12_2013.tif  fabas_12_10_2013.tif
```

10.1.2 Variables

In shell, a variable is a string (not a number). It can be defined as:

```
var1='Mathieu' # Store "Mathieu" in variables "var1"
var2='Fauvel'
var3='34'
```

Be careful to spaces: there are no spaces, otherwise an error is returned! A variable is displayed using the `echo` function and the variable is accessed with the command `$`.

```
echo $var1 $var2      # print "Mathieu Fauvel"
echo "$var3 ans"      # print "33 ans"
echo '$var3 ans'      # print "$var3 ans"
```

```
Mathieu Fauvel
34 ans
$var3 ans
```

Note the difference between the simple quote ' and the double quote ". The simple quote does not evaluate the variable while the double quote does.

It is possible to pass parameters to the script, solely by adding them when the script is called. They are accessible using the command $ following by the order number of appearance when the script is called. Let define the `script.sh` file.

```
# ./script.sh Name FamilyName Age
echo $1 $2
echo "J ai (eu) $3 ans !"
```

When we do this, we have the following output:

```
chmod +x script.sh
./script.sh Mathieu Fauvel 33
```

```
Mathieu Fauvel
J ai (eu) 33 ans !
```

10.1.3 Loop

As in any programming language, loop are very useful to apply a series of processing to several elements of a sequence. The example below applies a processing on all *tif* files of the current directory:

```
for i in *.tif # For all tif file
do
    cp $i ndvi_$i # create a new file and add ndvi_ at the beginning of the filename
done
```

10.1.4 Sequence

It is possible to define sequences of string like this:

```
for name in bayes libsvm knn rf
do
    echo $name
done
```

```
bayes
libsvm
knn
rf
```

Sequences of numbers can be defined like this:

```
for i in `seq 1 5`
do
echo $i
done
```

```
1
2
3
4
5
```

10.2 Short introduction to Python

A good starting point is the following link: http://kitchingroup.cheme.cmu.edu/pycse/pycse.html. Here, I just review few things that are usefull for the labwork. But python is far more than this short introduction.

10.2.1 String

Handling strings with python is very easy. It is possible to add strings together, as with number! Pay attention to spaces...

```
name="Mathieu"
surname="Fauvel"
print name + surname
```

```
MathieuFauvel
```

To use numbers in strings, it is necessary to convert them, using the function `str`

```
print "Bonjour j\'ai eu " + str(33) + " ans"
```

```
Bonjour j'ai eu 33 ans
```

10.2.2 Loop

It is very easy to iterate over a list with python. The list can be made of numbers, strings etc ... Since a list is iterable, defining a `for` loop is just:

```
listeNumber = [1,2,3,4]
print listeNumber
for item in listeNumber:
    print(item)

listeString = ['knn','bayes','libsvm','rf']
print listeString
for item in listeString:
    print(item)
```

```
[1, 2, 3, 4]
1
2
3
4
['knn', 'bayes', 'libsvm', 'rf']
knn
bayes
libsvm
rf
```

10.2.3 Glob

The glob module finds all the path-names matching a given pattern. It uses standard Unix (shell) path expansion rules. However, results are returned in arbitrary order and therefore sometimes ordering operation is necessary. It returns a list of pathnames, or a iterator which can be useful for large processing. Below some examples to see how it works. First, check what is in my *figures* directory:

```
ls figures/
```

```
google_bridge.jpg
label_fabas.jpg
label_fabas.jpgw
old_map.jgw
old_map.jpg
pixel.pdf
quicklook_fabas_10_12_2013.jpg
quicklook_fabas_12_10_2013.jpg
quicklook_seg_eau.png
sits_f2.pgw
sits_f2.png
take5spot5.png
tsunami_after.jpg
tsunami_before.jpg
```

If we want to get all the files, we just need to do

```
import glob

files = glob.glob("figures/*")
for files_ in files:
    print files_
```

```
figures/sits_f2.png
figures/quicklook_fabas_12_10_2013.jpg
figures/tsunami_after.jpg
figures/take5spot5.png
figures/sits_f2.pgw
figures/quicklook_fabas_10_12_2013.jpg
figures/pixel.pdf
figures/label_fabas.jpg
figures/tsunami_before.jpg
figures/old_map.jpg
figures/quicklook_seg_eau.png
figures/label_fabas.jpgw
figures/old_map.jgw
figures/google_bridge.jpg
```

If we only want the *png* files:

```
import glob

files = glob.glob("figures/*.png")
for files_ in files:
    print files_
```

```
figures/sits_f2.png
figures/take5spot5.png
figures/quicklook_seg_eau.png
```

The iterator is `iglob`, it does the same job than `glob`, but without storing all the results simultaneously.

```
import glob

for files_ in glob.iglob("figures/*.png"):
    print files_
```

```
figures/sits_f2.png
figures/take5spot5.png
figures/quicklook_seg_eau.png
```

10.2.4 Argparse

Argparse (https://docs.python.org/3.6/library/argparse.html) is module to parse options and arguments from the command-line interface. It defines what are the mandatory argument, generates help and usages messages and errors at runtime.

For instance, suppose we have a function that needs two parameters: the name of a multispectral file and the size of the template filter. Argparse handles everything:

```
import argparse

# Initialization of the filter
parser = argparse.ArgumentParser()

# Add arguments
parser.add_argument("-in",dest="image",help="Image to be processed",type=str)
parser.add_argument("-p",help="Size of the template",type=int,default=1)

args = parser.parse_args()

print args.image
print args.p
```

```
None
1
```