FlussTools

Release latest

FlussTeam

Aug 30, 2023

CONTENTS

The analysis, research, and science-based design of hydrological ecosystems involve complex challenges for interdisciplinary experienced teams. We have created *flusstools* to meet the complex challenges and to at least partially automate time-consuming, repetitive processes of processing field data, numerical model outputs, or geospatial data. "We" stands for individuals with a great passion for rivers (German: "Flüsse") and programming. Most of us work (or have worked) at the University of Stuttgart (Germany) at the Institute for Modelling Hydraulic and Environmental Systems. Because we have a strong commitment to transparent open-source applications, we created *flusstools* and we welcome new team members (for example, to add or amend a module) at any time - read more in the *Become a contributor* section.

Important: Follow the installation instructions on hydro-informatics.com to make sure that GDAL works on your computer as desired.

Currently, *flusstools* comes with the following modules:

- *bedanalyst* - for plotting and numeric analysis of riverbed characteristic to identify, for instance, clogging (developers: Beatriz Negreiros, and Ricardo Barros).
- *geotools* - versatile functions for processing spatial data for fluvial ecosystem analyses based on gdal and other open source libraries (developers: Kilian Mouris, Beatriz Negreiros, and Sebastian Schwindt). The functions are explained with the geospatial Python tutorials on hydro-informatics.com and the HydroMorphodynamics YouTube channel.
- *fuzzycorr* - a map comparison toolkit that builds on fuzzy sets to assess the accuracy of (numerical) river models (principal developer: Beatriz Negreiros).
- *lidartools* - *Python* wrappers for lastools (forked and modified from Kenny Larrieu).

How to cite FlussTools

If our codes helped you to accomplish your work, we won't ask you for a coffee, but to cite and spread the utility of our code - Thank you!

```
@software{flussteam_tools_2023,
          author       = {Sebastian Schwindt and
                          Beatriz Negreiros and
                          Ricardo Barros and
                          Niklas Henning and
                          Kilian Mouris},
          title        = {FlussTools},
          year         = 2023,
          publisher    = {GitHub \& Center for Open Science (OSF)},
          version      = {v1.1.7},
          doi          = {10.17605/OSF.IO/G7K52},
          url          = {https://doi.org/10.17605/OSF.IO/G7K52}
        }
```

The documentation is also as available as style-adapted PDF.

CHAPTER

ONE

INSTALLATION

Working with *flusstools* is platform independent, but the favorable installation procedure varies among platforms (e.g., *Linux* or *Windows*).

We recommend *Windows* user to use *Anaconda* and *conda* environments. *Linux* users will have a better experience with *pip*-installing *flusstools*. The differences stem from the way how GDAL is installed on the two platforms. *macOS* users may want to follow the *Linux* instructions, even though we could not yet test the installation of *flusstools* on *macOS*. For *Linux* users: before *pip install flusstools*, make sure your *pip* is updated (*python -m pip install –upgrade pip*) to avoid incompatibilities with Python wheels in Linux.

flusstools is tailored for applications in water resources research and engineering and this is why the detailed instructions about the installation of flusstools are provided with the hydro-informatics eBook (at https://hydro-informatics.com).

CHAPTER

TWO

BASIC USAGE

2.1 Import

Import flusstools:

```
import flusstools as ft
```

Or one of its modules:

```
from flusstools import geotools
```

New to Python? Take a look at the Python tutorial for water resources engineering and research at hydro-informatics.com

2.2 Example

```
from flusstools import geotools as gt
raster, array, geo_transform = gt.raster2array("/sample-data/froude.tif")
type(raster)
<class 'osgeo.gdal.Dataset'>
type(array)
<class 'numpy.ndarray'>
type(geo_transform)
<class 'tuple'>
print(geo_transform)
(6748604.7742, 3.0, 0.0, 2207317.1771, 0.0, -3.0)
```

2.3 Requirements (Dependencies)

FlussTools requires geospatial processing libraries, which cannot be directly resolved by running *setup.py*. For this reason, we recommend to either install a virtual environment with requirements.txt or a conda environment with environment.yml to check out the following dependencies on non-standard Python libraries:

Ext. libs.		
alphashape	laspy	rasterio
earthpy	mapclassify	rasterstats
gdal	matplotlib	tk
geojson	numpy	scipy
geopandas	pandas	shapely
h5py	pip	tabulate
networkx	pyshp	plotly

CHAPTER

THREE

BEDANALYST

Algorithms for analyzing riverbed clogging through visualization functions, geospatial interpolation, and a novel fuzzy degree of clogging

The *BedAnalyst* (`flusstools.bedanalyst`) modules provide *Python3* functions for substrate sample analysis and a fuzzy logic assessment of so-called riverbed clogging.

3.1 Usage

3.1.1 Import

Import `bedanalyst` from flusstools:

```
from flusstools import bedanalyst as bea
```

3.1.2 Example (code block)

```
from flusstools import bedanalyst as bea
clogging_pars = bea.fuzzy_analyze("/sample-data/sample.csv")
```

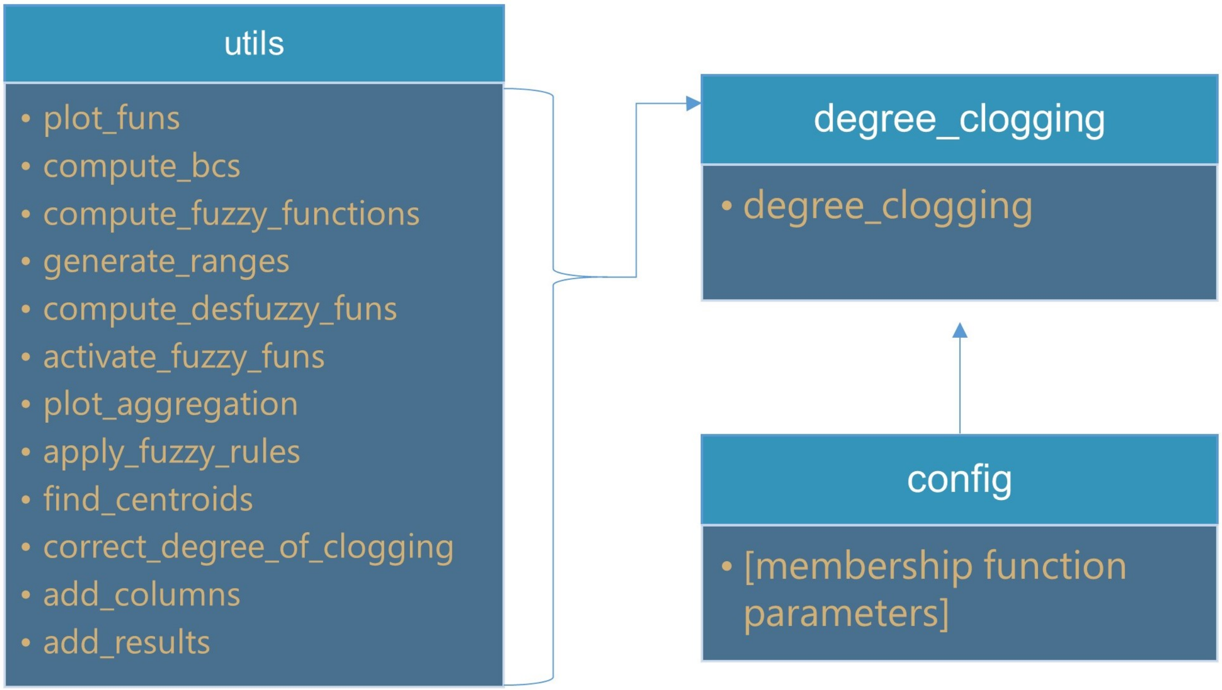
3.1.3 Example (showcase)

A showcase is provided in the flusstools example degree of clogging.

3.2 Code structure

The following diagram highlights function locations in Python scripts and how those are linked to each other.

The modules `cd_profiles`, `nABP_degree_clogging`, and `interp_z2shp` are independent from the `degree_clogging` module.



3.3 Script and function docs

3.3.1 Package Head: `bedanalyst`

This module contains all the necessary mathematical definitions of the membership functions, which may be altered by the user, if necessary.

The first input is the dictionary containing two points for the fuzzy and defuzzification functions. Two points define a function and the have the following format:

(parameter_values, corresponding_membership_values)

For example, for the parameter fine sediment share, the point with the lowest value in the y-axis is written as follows:

(fs_c_llow, fs_mu_c_llow)

where fs stands for fine sediment share, c indicates the membership function associated to clogging, mu indicates the membership value, and llow indicates the relative position of the point in the curve.

The second input is the local address of the csv file containing the parameters of the samples.

The third input is composed by two booleans that indicates the algorithm to print the fuzzy functions and the aggregation functions inside the folder output.

3.3.2 Another algorithm `degree_clogging`

This module calls the necessary functions to perform the computation of degree of clogging.

`flusstools.bedanalyst.degree_clogging.`**`degree_clogging`**(*df_samples*, *output_csv_path*, *plot=[False, False]*)

Function for computing degree of clogging using the input riverbed parameter along the riverbed depth:

- Fine Sediment Saare/Fraction (fsf/fss): [%]
- Hydraulic Conductivity (kf): [m/s]
- Porosity (n): [-]
- Interstitial Dissolved Oxygen Content (IDOC): [mg/L]
- Bridging criterion according to Huston & Fox (2015; referred as 'ratio' here): [-]

Parameters

- **df_samples** (*pandas.DataFrame*) – df containing the columns 'id' (sample id), 'fss', 'kf', 'n', 'idoc' and 'ratio'
- **output_csv_path** (*str*) – path to output csv containing the results of the fuzzy inference and final computed degree of clogging
- **plot** (*list*) – List of two boolean objects indicating if the plots for the aggregation function and the fuzzy
- **required** (*membership functions of the above mentione dparameters is required. Should be True if*) –
- **respectively.** –

Returns
None

3.3.3 Another algorithm `interp_z2shp`

`flusstools.bedanalyst.interp_z2shp.`**`interp_z2shp`**(*df*, *lonlat*, *crs*, *sample_column*, *interp_at_z_stamps*, *new_attr_names*, *meas_at_cols*, *path_shp*)

Interpolates vertical riverbed measurements (e.g., kf, IDOS) to desired z (vertical) stamps, enters them as attributes for creating a point shapefile

Parameters

- **df** (*pandas.DataFrame*) – df with rows indicating samples and columns indicating parameters
- **lonlat** (*tuple of str*) – name of the columns containing longitude and latitude, respectively (x, y)
- **crs** (*str*) – of type 'epsg:xxxx or xxxxx', coordinate system of the input longitude and latitude values
- **sample_column** (*str*) – name of the column in the df which contains the sample names
- **interp_at_z_stamps** (*numpy.array of floats*) – contains the z (vertical) stamps where the measurement should be interpolated

- **new_attr_names** (*list of str*) – names of the attributes referring to the selected new z stamps.
- **meas_at_cols** (*tuple of str*) – contains the column names as a tuple (z_stamp, measurement) of the df that have the vertical spatial stamp of the measurement and the value measured at the corresponding z stamp.
- **path_shp** (*str*) – path to save the shapefile

Returns
geopandas.GeoDataFrame

3.3.4 Another algorithm utils

This module contains the functions called by main.

flusstools.bedanalyst.utils.**activate_fuzzy_funs**(*probe*, *dc_param_range*, *dc_fuzzy_funs*)

Function to compute the membership values of the fuzzy functions for the parameters of a real sample. :param probe: float values of the parameters of a sample in the following order (F.S, kf, n, IDOC, ratio) :type probe: tuple :param dc_param_range: arrays of float values of the six parameters defined into utils.generate_ranges() :type dc_param_range: dict :param dc_fuzzy_funs: arrays with the membership values of the fuzzy functions :type dc_fuzzy_funs: dict

Returns
fuzzy membership float values corresponding to the parameter values of the real sample

Return type
dc_fuzzy_activated (dict)

flusstools.bedanalyst.utils.**add_columns**(*df_samples*)

Function to add columns of csv output

Parameters
df_samples (*Dataframe*) – dataframe with the parameters of the samples

Returns
same input Dataframe but with new columns

Return type
df_samples (Dataframe)

flusstools.bedanalyst.utils.**add_results**(*df*, *step*, *degree_of_clogging_corrected*, *degree_of_clogging*, *dc_mu_desfuzzy_values*, *dc_af*)

Function to add computed result to output-Dataframe

Parameters

- **df** (*Dataframe*) – input Dataframe
- **step** (*int*) – nth sample
- **degree_of_clogging_corrected** (*float*) – dregree of clogging corrected to interval [0, 1]
- **degree_of_clogging** (*float*) – degree of clogging in the
- **[centroid_of_no_clogging** (*interval*) –
- **centroid_of_strong_clogging]** –
- **dc_mu_desfuzzy_values** (*dict*) – three float values of the sample-activated defuzzification functions

- **dc_af** (*dict*) – membership float values of the activated fuzzy functions
- **step** – nth sample

Returns
output Dataframe

Return type
df (Dataframe)

`flusstools.bedanalyst.utils.`**`apply_fuzzy_rules`**(*dc_af=None*, *dc_desfuzzy_funs=None*, *centroid=False*, *mu_list=None*)

Function to choose membership value of defuzzification functions based on the fuzzy rules.

Parameters

- **dc_af** (*dict*) – membership values of fuzzy functions of a sample
- **dc_desfuzzy_funs** (*dict*) – arrays with the membership values of the defuzzification functions
- **centroid** (*boolean*) – True to correct the limits of degree of clogging to [0,1]
- **mu_list** (*list*) – corrected membership function values of the activated defuzzification functions

Returns
array of membership values that define area under the curve of the defuzzification functions dc_mu_defuzzy_values (dict): three float values of the sample-activated defuzzification functions

Return type
dc_mu_defuzzy (dict)

`flusstools.bedanalyst.utils.`**`compute_bcs`**(*dc_limits*)

Function to compute bs and cs constants that define the sigmoid fuzzy membership functions (y = 1 / (1. + exp[-c * (x - b)]))

Parameters
dc_limits (*dict*) – thresholds of the membership functions defined in config.py

Returns
b values of the membership functions dc_c (dict): c values of the membership functions

Return type
dc_b (dict)

`flusstools.bedanalyst.utils.`**`compute_desfuzzy_funs`**(*dc_param_range*, *dc_b*, *dc_c*)

Function to compute defuzzification membership functions. The functions for high and low degree of clogging are Sigmoids and for medium degree of clogging is Gaussian. :param dc_param_range: arrays of float values of the six parameters defined into utils.generate_ranges()

Returns
arrays with the membership values of the defuzzification functions

Return type
(dict)

`flusstools.bedanalyst.utils.`**`compute_fuzzy_functions`**(*dc*, *dc_b*, *dc_c*)

Function to compute bs and cs constants that define the sigmoid fuzzy membership functions (y = 1 / (1. + exp[-c * (x - b)]))

Parameters

- **dc_limits** (*dict*) – thresholds of the membership functions defined in config.py
- **dc_b** (*dict*) – b values of the membership functions
- **dc_c** (*dict*) – c values of the membership functions

Returns
arrays with the membership values of the fuzzy functions

Return type
(dict)

`flusstools.bedanalyst.utils.`**`correct_degree_of_clogging`**`(`*dc_defuzzy_centroids*, *degree_of_clogging*`)`

Function to correct degree of clogging from the interval [centroid_of_no_clogging, centroid_of_strong_clogging] to [0, 1]

Parameters

- **degree_of_clogging** (*float*) – original degree of clogging
- **dc_defuzzy_centroids** (*dict*) – two float values that represent the centroids of sc and nc defuzzi-functions

Returns
degree of clogging in the interval [0, 1]

Return type
degree_of_clogging_corrected (float)

`flusstools.bedanalyst.utils.`**`find_centroids`**`(`*dc_desfuzzy_funs*, *dc_param_range*`)`

Function to find centroids of the non clogging and strong clogging defuzzification functions

Parameters

- **dc_param_range** (*dict*) – arrays of float values of the six parameters defined into utils.generate_ranges()
- **dc_desfuzzy_funs** (*dict*) – arrays with the membership values of the defuzzification functions

Returns
two float values that represent the centroids of sc and nc defuzzi-functions

Return type
dc_defuzzy_centroids (dict)

`flusstools.bedanalyst.utils.`**`generate_ranges`**`()`

Function to define de ranges of the parameters

Parameters
None –

Returns
array with the ranges of the parameters

Return type
(dict)

`flusstools.bedanalyst.utils.`**`plot_aggregation`**`(`*dc_param_range*, *dc_mu_desfuzzy*, *dc_desfuzzy_funs*, *activation*, *degree_of_clogging*, *aggregated*, *step*`)`

Function to compute the membership values of the fuzzy functions for the parameters of a real sample. :param dc_param_range: arrays of float values of the six parameters defined into utils.generate_ranges() :type dc_param_range: dict :param dc_mu_desfuzzy: defuzzified membership float values corresponding to the parameter values of the real sample

Parameters

- **dc_desfuzzy_funs** (*dict*) – arrays with the membership values of the defuzzification functions
- **activation** (*float*) – degree of clogging that equals to the center of mass of tha sum of the areas under
- **functions** (*the activated defuzzification*) –
- **degree_of_clogging** (*float*) – degree of clogging correct between 0 and 1 in utils.correct_degree_of_clogging()
- **aggregated** (*array*) – membership float values that define the summed area below the
- **functions.** (*activated defuzzification*) –
- **step** (*int*) – integer that represents the nth sample

Returns
None

flusstools.bedanalyst.utils.**plot_funs**(*dc_param_range*, *dc_fuzzy_funs*, *dc_disfuzzy_funs*)

Function to plot the membership functions of the parameters and defuzzyfication membership functions into one plot.

Parameters

- **dc_param_range** (*dict*) – arrays of float values of the six parameters defined into utils.generate_ranges()
- **dc_fuzzy_funs** (*dict*) – arrays of membership fuzzy functions values of the given ranges of the six parameters
- **dc_disfuzzy_funs** (*dict*) – arrays of membership defuzzy functions values of the given ranges of the six parameters

Returns
None

CHAPTER

FOUR

GEOTOOLS

Geospatial Functions for Hydraulics and Morphodynamics

The *GeoTools* (`flusstools.geotools`) modules provide *Python3* functions for many sorts of river-related analyses with geospatial data (e.g., for working with numerical model input and output). The package is intended as support material for the hydro-informatics eBook.

4.1 Usage

4.1.1 Import

Import `geotools` from flusstools:

```
from flusstools import geotools as geo
```

4.1.2 Example (code block)

```
from flusstools import geotools as geo
raster, array, geo_transform = geo.raster2array("/sample-data/froude.tif")
type(raster)
# >>> <class 'osgeo.gdal.Dataset'>
type(array)
# >>> <class 'numpy.ndarray'>
type(geo_transform)
# >>> <class 'tuple'>
print(geo_transform)
# >>> (6748604.7742, 3.0, 0.0, 2207317.1771, 0.0, -3.0)
```

4.1.3 Example (showcase)

A showcase is provided with the `ROOT/examples/geotools-showcase/georeference_tifs.py` script that illustrates geo-referencing *tif* images that do not have a projection assigned.

4.2 Code structure

The following diagram highlights function locations in Python scripts and how those are linked to each other.

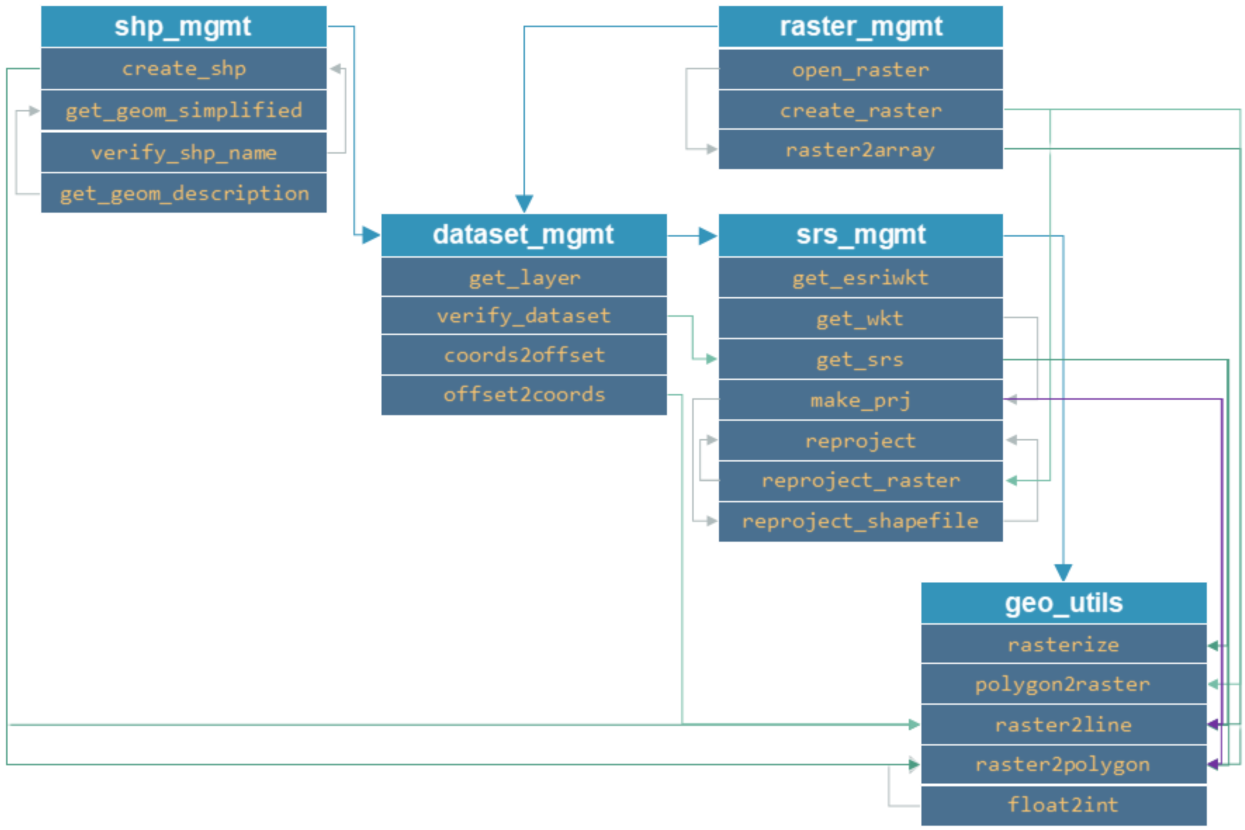


Fig. 4.1: *Diagram of the code structure (needs to be updated).*

4.3 Script and function docs

4.3.1 Package Head: `geotools`

`geotools` is a package for creating, modifying, and transforming geospatial datasets.

`flusstools.geotools.geotools.`**`float2int`**`(`*raster_file_name*, *band_number=1*`)`

Converts a float number raster to an integer raster (required for converting a raster to a polygon shapefile).

Parameters

- **`raster_file_name`** (*`str`*) – Target file name, including directory; must end on `".tif"`.
- **`band_number`** (*`int`*) – The raster band number to open (default: 1).

Returns
`"path/to/ew_raster_file.tif"`

Return type
str

`flusstools.geotools.geotools.`**`raster2line`**(*raster_file_name*, *out_shp_fn*, *pixel_value*, *max_distance_method='simplified'*)

Converts a raster to a line shapefile, where `pixel_value` determines line start and end points.

Parameters

- **`raster_file_name`** (*`str`*) – of input raster file name, including directory; must end on `".tif"`.
- **`out_shp_fn`** (*`str`*) – of target shapefile name, including directory; must end on `".shp"`.
- **`pixel_value`** (`int` or `float`) – Pixel values to connect.
- **`max_distance_method`** – change to (pixel) `"width"` or `"height"` to force lines to exactly follow pixels (no triangulation).

`flusstools.geotools.geotools.`**`raster2polygon`**(*file_name*, *out_shp_fn*, *band_number=1*, *field_name='values'*)

Converts a raster to a polygon shapefile.

Parameters

- **`file_name`** (*`str`*) – Target file name, including directory; must end on `".tif"`
- **`out_shp_fn`** (*`str`*) – Shapefile name (with directory e.g., `"C:/temp/poly.shp"`)
- **`band_number`** (*`int`*) – Raster band number to open (default: `1`)
- **`field_name`** (*`str`*) – Field name where raster pixel values will be stored (default: `"values"`)
- **`add_area`** – If `True`, an "area" field will be added, where the area in the shapefiles unit system is calculated (default: `False`)

`flusstools.geotools.geotools.`**`rasterize`**(*in_shp_file_name*, *out_raster_file_name*, *pixel_size=10*, *no_data_value=-9999*, *rdtype=gdal.GDT_Float32*, *overwrite=True*, *interpolate_gap_pixels=False*, ***kwargs*)

Converts any ESRI shapefile to a raster.

Parameters

- **`in_shp_file_name`** (*`str`*) – A shapefile name (with directory e.g., `"C:/temp/poly.shp"`)
- **`out_raster_file_name`** (*`str`*) – Target file name, including directory; must end on `".tif"`
- **`pixel_size`** (*`float`*) – Pixel size as multiple of length units defined in the spatial reference (default: `10`)
- **`no_data_value`** (*`int OR float`*) – Numeric value for no-data pixels (default: `-9999`)
- **`rdtype`** (*`gdal.GDALDataType`*) – The raster data type (default: `gdal.GDT_Float32` (32 bit floating point)
- **`overwrite`** (*`bool`*) – Overwrite existing files (default: `True`)
- **`interpolate_gap_pixels`** (*`bool`*) – Fill empty pixels that are not touched by a shapefile element with interpolated values (default: `False`)

Keyword Arguments

- **`field_name`** (*`str`*) – Name of the shapefile's field with values to burn to raster pixel values.
- **`radius1`** (*`float`*) – Define the x-radius for interpolating pixels (default: `-1`, corresponding to infinity). Only applicable `with interpolate_gap_pixels`.

- **radius2** (*float*) – Define the y-radius for interpolating pixels (default: -1, corresponding to infinity). Only applicable with interpolate_gap_pixels.
- **power** (*float*) – Power of the function for interpolating pixel values (default: 1.0, corresponding to linear).
- **smoothing** (*float*) – Smoothing parameter for interpolating pixel values (default: 0.0).
- **min_points** (*int*) – Minimum number of points to use for interpolation. If the interpolator cannot find at least min_points for a pixel, it assigns a no_data value to that pixel (default: 0).
- **max_points** (*int*) – Maximum number of points to use for interpolation. The interpolator will not use more than max_points closest points to interpolate a pixel value (default: 0).

Hints:

More information on pixel value interpolation: interpolate_gap_pixels=True interpolates values at pixels that are not touched by any las point. The pixel value interpolation uses gdal_grid (i.e., its Python bindings through gdal.Grid()). Control the interpolation parameters with the keyword arguments radius1, radius2, power, max_points, min_points, and smoothing..

Returns

Creates the GeoTIFF raster defined with out_raster_file_name (success: 0, otherwise None).

Return type

int

4.3.2 Raster Management raster_mgmt

flusstools.geotools.raster_mgmt.**clip_raster**(*polygon*, *in_raster*, *out_raster*)

Clips a raster to a polygon.

Parameters

- **polygon** (*str*) – A polygon shapefile name, including directory; must end on ".shp".
- **in_raster** (*str*) – Name of the raster to be clipped, including its directory.
- **out_raster** (*str*) – Name of the target raster, including its directory.

Returns

Creates a new, clipped raster defined with out_raster.

Return type

None

flusstools.geotools.raster_mgmt.**create_raster**(*file_name*, *raster_array*, *bands=1*, *origin=None*, *epsg=4326*, *pixel_width=10.0*, *pixel_height=10.0*, *nan_val=-9999.0*, *rdtype=gdal.GDT_Float32*, *geo_info=False*, *rotation_angle=None*, *shear_pixels=True*, *options=['PROFILE=GeoTIFF']*)

Converts an ndarray (numpy.array) to a GeoTIFF raster.

Parameters

- **file_name** (*str*) – Target file name, including directory; must end on ".tif".
- **raster_array** (ndarray or list) – 2d-array (no bands) or list (bands) of 2-darrays of values to rasterize. If a list of 2d-arrays is provided, the length of the list will correspond to the number of bands added to the raster (supersedes bands).

- **bands** (*int*) – Number of bands to write to the raster (default: 1).
- **origin** (*tuple*) – Coordinates (x, y) of the origin.
- **epsg** (*int*) – EPSG:XXXX projection to use (default: `4326`).
- **pixel_height** (*float OR int*) – Pixel height as multiple of the base units defined with the EPSG number (default: `10` meters).
- **pixel_width** (*float OR int*) – Pixel width as multiple of the base units defined with the EPSG number (default: `10` meters).
- **nan_val** (`int` or `float`) – No-data value to be used in the raster. Replaces non-numeric and `np.nan` in the `ndarray`. (default: `geoconfig.nan_value`).
- **rdtype** – gdal.GDALDataType raster data type (default: gdal.GDT_Float32 (32 bit floating point).
- **geo_info** (*tuple*) – Defines a `gdal.DataSet.GetGeoTransform` object and supersedes `origin`, `pixel_width`, `pixel_height` (default: `False`).
- **rotation_angle** (*float*) – Rotate (in degrees) not North-up rasters. The default value (`0`) corresponds to north-up (only modify if you know what you are doing).
- **shear_pixels** (*bool*) – Use with `rotation_angle` to shear pixels as well (default: `True`).
- **options** (*list*) – Raster creation options - default is ['PROFILE=GeoTIFF']. Add 'PHOTOMETRIC=RGB' to create an RGB image raster.

Returns
`0` if successful, otherwise `-1`.

Return type
int

Hint: For processing airborne imagery, the `rotation_angle` corresponds to the bearing angle of the aircraft with reference to true, not magnetic North.

`flusstools.geotools.raster_mgmt.`**`open_raster`**(*file_name*, *band_number=1*)

Opens a raster file and accesses its bands.

Parameters

- **file_name** (*str*) – The raster file directory and name.
- **band_number** (*int*) – The Raster band number to open (default: 1).

Returns
A raster dataset a Python object. osgeo.gdal.Band: The defined raster band as Python object.

Return type
osgeo.gdal.Dataset

`flusstools.geotools.raster_mgmt.`**`raster2array`**(*file_name*, *band_number=1*)

Extracts a numpy `ndarray` from a raster.

Parameters

- **file_name** (*str*) – Target file name, including directory; must end on `".tif"`.
- **band_number** (*int*) – The raster band number to open (default: 1).

Returns
three-elements of [osgeo.DataSet of the raster, numpy.ndarray of the raster band_numer (input) where no-data values are replaced with np.nan, osgeo.GeoTransform of the original raster]

Return type
list

flusstools.geotools.raster_mgmt.**remove_tif**(*file_name*)

Removes a GeoTIFF and its dependent files (e.g., xml).

Parameters
file_name (*str*) – Directory (path) and name of a GeoTIFF

Returns
Removes the provided file_name and all dependencies.

Return type
None

flusstools.geotools.raster_mgmt.**xy_raster_shift**(*file_name*, *x_shift*, *y_shift*, *bands=1*, *rdtype=gdal.GDT_Float32*, *nan_val=-9999.0*, *compress=True*, *options=['PROFILE=GeoTIFF']*, *compress_config=['COMPRESS=LZW', 'TILED=YES']*)

Creates new geotiff raster with shifts in x and y direction. If enabled compresses it also compresses file.

Args: file_name (string): File path of GeoTiff x_shift (float OR int): Shift origin in x direction. *Check that correct units are used. Example: wgs 84 is in degrees y_shift (float OR int): Shift origin in y direction. *Check that correct units are used. Example: wgs 84 is in degrees bands (int): Number of bands default is 1, however check raster to see how many are required. Example: RGBA=4 rdtype: gdal.GDALDataType raster data type (default: gdal.GDT_Float32 (32 bit floating point). nan_val (int or float): No-data value to be used in the raster. Replaces non-numeric and np.nan in the ndarray. (default: geoconfig.nan_value). compress (Bool): If True creates compressed version of the GeoTiff options (list): Raster creation options - default is ['PROFILE=GeoTIFF']. Add 'PHOTOMETRIC=RGB' to create an RGB image raster. compress_config: (list) Compress creation options - default is ["COMPRESS=LZW", "TILED=YES"] LZW=Lempel-Ziv-Welch-Algorithm See gdal.Translate for more options

Returns
0 if successful, otherwise -1.

Return type
int

Hint: For drone rasters try bands=4 (rgba) rdtype=gdal.GDT_Byte nan_val=0 options=['PROFILE=GeoTIFF','PHOTOMETRIC=RGB'])

Bugs: Issues displaying logging

4.3.3 Shapefile Management `shp_mgmt`

`flusstools.geotools.shp_mgmt.`**`create_shp`**`(`*shp_file_dir*, *overwrite=True*, **args*, ***kwargs*`)`

Creates a new shapefile with an optionally defined geometry type.

Parameters

- **`shp_file_dir`** (*`str`*) – of the (relative) shapefile directory (ends on `".shp"`).
- **`overwrite`** (*`bool`*) – If `True` (default), existing files are overwritten.
- **`layer_name`** (*`str`*) – The layer name to be created. If `None`: no layer will be created.
- **`layer_type`** (*`str`*) – Either `"point"`, `"line"`, or `"polygon"` of the `layer_name`. If `None`: no layer will be created.

Returns

An `ogr` shapefile (Python object)

Return type

osgeo.ogr.DataSource

Hint: Use the `layer_name` and `layer_type` kwargs along with each other. Keeping these parameters default is deprecated.

`flusstools.geotools.shp_mgmt.`**`get_geom_description`**`(`*layer*`)`

Gets the WKB Geometry Type as string from a shapefile layer.

Parameters

`layer` (*`osgeo.ogr.Layer`*) – A shapefile layer.

Returns

WKB (binary) geometry type

Return type

str

`flusstools.geotools.shp_mgmt.`**`get_geom_simplified`**`(`*layer*`)`

Gets a simplified geometry description (either point, line, or polygon)

as a function of the WKB Geometry Type of a shapefile layer.

Parameters

`layer` (*`osgeo.ogr.Layer`*) – A shapefile layer.

Returns

Either WKT-formatted point, line, or polygon (or unknown if invalid layer).

Return type

str

`flusstools.geotools.shp_mgmt.`**`polygon_from_shapepoints`**`(`*shapepoints*, *polygon*, *alpha=nan*`)`

Creates a polygon around a cloud of `shapepoints`.

Parameters

- **`shapepoints`** (*`str`*) – Point shapefile name, including its directory.
- **`polygon`** (*`str`*) – Target shapefile filename, including its directory.
- **`alpha`** (*`float`*) – Coefficient to adjust; the lower it is, the more slim will be the polygon.

Returns
Creates the polygon shapefile defined with `polygon`.

Return type
None

`flusstools.geotools.shp_mgmt.`**`verify_shp_name`**`(`*shp_file_name*, *shorten_to=13*`)`

Ensure that the shapefile name does not exceed 13 characters. Otherwise, the function shortens the `shp_file_name` length to `shorten_to=N` characters.

Parameters

- **`shp_file_name`** (*`str`*) – A shapefile name (with directory e.g., `"C:/temp/poly.shp"`).
- **`shorten_to`** (*`int`*) – The number of characters the shapefile name should have (default: `13`).

Returns
A shapefile name (including path if provided) with a length of `shorten_to`.

Return type
str

4.3.4 Projection Management `srs_mgmt`

`flusstools.geotools.srs_mgmt.`**`get_esriwkt`**`(`*epsg*`)`

Gets esriwkt-formatted spatial references with epsg code online.

Parameters
`epsg` (*`int`*) – EPSG Authority Code

Returns
An esriwkt string (if an error occur, the default epsg=``4326`` is used).

Return type
str

Example

Call this function with `get_esriwkt(4326)` to get a return, such as `'GEOGCS["GCS_WGS_1984",DATUM[...],...]`.

Hint: This function requires an internet connection: Loads spatial reference codes as `"https://spatialreference.org/ref/sr-org/{0}/esriwkt/".format(epsg)` For instance, `epsg=3857` yields `"https://spatialreference.org/ref/sr-org/3857/esriwkt/"`

`flusstools.geotools.srs_mgmt.`**`get_srs`**`(`*dataset*`)`

Gets the spatial reference of any `gdal.Dataset`.

Parameters
`dataset` (*`gdal.Dataset`*) – A shapefile or raster.

Returns
A spatial reference object.

Return type
osr.SpatialReference

`flusstools.geotools.srs_mgmt.`**`get_wkt`**(*epsg*, *wkt_format='esriwkt'*)

Gets WKT-formatted projection information for an epsg code using the `osr` library.

Parameters

- **epsg** (*int*) – epsg Authority code
- **wkt_format** (*str*) – of wkt format (default is esriwkt for shapefile projections)

Returns
WKT (if error: returns default corresponding to `epsg=4326`).

Return type
str

`flusstools.geotools.srs_mgmt.`**`make_prj`**(*shp_file_name*, *epsg*)

Generates a projection file for a shapefile.

Parameters

- **shp_file_name** (*str*) – of a shapefile name (with directory e.g., `"C:/temp/poly.shp"`).
- **epsg** (*int*) – EPSG Authority Code

Returns
Creates a projection file (`.prj`) in the same directory and with the same name of `shp_file_name`.

Return type
None

`flusstools.geotools.srs_mgmt.`**`reproject`**(*source_dataset*, *new_projection_dataset*)

Re-projects a dataset (raster or shapefile) onto the spatial reference system of a (shapefile or raster) layer.

Parameters

- **source_dataset** (*gdal.Dataset*) – Shapefile or raster.
- **new_projection_dataset** (*gdal.Dataset*) – Shapefile or raster with new projection info.

Returns
If the source is a raster, the function creates a GeoTIFF in same directory as `source_dataset` with a `"_reprojected"` suffix in the file name. **If the source is a shapefile**, the function creates a shapefile in same directory as `source_dataset` with a `"_reprojected"` suffix in the file name.

Return type
None

`flusstools.geotools.srs_mgmt.`**`reproject_raster`**(*source_dataset*, *source_srs*, *target_srs*)

Re-projects a raster dataset. This function is called by the `reproject` function.

Parameters

- **source_dataset** (*osgeo.ogr.DataSource*) – Instantiates with an `ogr.Open(SHP-FILE)`.
- **source_srs** (*osgeo.osr.SpatialReference*) – Instantiates with `get_srs(source_dataset)`
- **target_srs** (*osgeo.osr.SpatialReference*) – Instantiates with `get_srs(DATASET-WITH-TARGET-PROJECTION)`.

Returns
Creates a new GeoTIFF raster in the same directory where `source_dataset` lives.

Return type
None

`flusstools.geotools.srs_mgmt.`**`reproject_shapefile`**`(`*source_dataset*, *source_layer*, *source_srs*, *target_srs*`)`

Re-projects a shapefile dataset. This function is called by the `reproject` function.

Parameters

- **`source_dataset`** (*`osgeo.ogr.DataSource`*) – Instantiates with `ogr.Open(SHP-FILE)`.
- **`source_layer`** (*`osgeo.ogr.Layer`*) – Instantiates with `source_dataset.GetLayer()`.
- **`source_srs`** (*`osgeo.osr.SpatialReference`*) – Instantiates with `get_srs(source_dataset)`.
- **`target_srs`** (*`osgeo.osr.SpatialReference`*) – Instantiates with `get_srs(DATASET-WITH-TARGET-PROJECTION)`.

Returns
Creates a new shapefile in the same directory where `source_dataset` lives.

Return type
None

4.3.5 Dataset Management (`dataset_mgmt`)

`flusstools.geotools.dataset_mgmt.`**`coords2offset`**`(`*geo_transform*, *x_coord*, *y_coord*`)`

Returns x-y pixel offset (inverse of the `offset2coords` function).

Parameters

- **`geo_transform`** – osgeo.gdal.Dataset.GetGeoTransform() object
- **`x_coord`** (*`float`*) – x-coordinate
- **`y_coord`** (*`float`*) – y-coordinate

Returns
Number of pixels `(offset_x, offset_y)`, both `int` .

Return type
tuple

`flusstools.geotools.dataset_mgmt.`**`get_layer`**`(`*dataset*, *band_number=1*`)`

Gets a `layer=band` (`RasterDataSet`) or `layer=ogr.Dataset.Layer` of any dataset.

Parameters

- **`dataset`** (`osgeo.gdal.Dataset` or `osgeo.ogr.DataSource`) – Either a raster or a shapefile.
- **`band_number`** (*`int`*) – Only use with rasters to define a band number to open (default is `1`).

Returns
`{"type": raster or vector or "None", layer":` if raster: `raster_band`, if vector: `GetLayer()`, else: `None}`

Return type
dict

`flusstools.geotools.dataset_mgmt.`**`offset2coords`**(*geo_transform*, *offset_x*, *offset_y*)

Returns x-y coordinates from pixel offset (inverse of `coords2offset` function).

Parameters

- **`geo_transform`** (*`osgeo.gdal.Dataset.GetGeoTransform`*) – The geo transformation to use.
- **`offset_x`** (*`int`*) – x number of pixels.
- **`offset_y`** (*`int`*) – y number of pixels.

Returns

Two `float` numbers of x-y-coordinates `(x_coord, y_coord)`.

Return type

tuple

`flusstools.geotools.dataset_mgmt.`**`verify_dataset`**(*dataset*)

Verifies if a dataset contains raster or vector data.

Parameters

`dataset` (`osgeo.gdal.Dataset` or `osgeo.ogr.DataSource`) – Dataset to verify.

Returns

Either "unknown", "raster", or "vector".

Return type

str

4.3.6 KML/KML File Management

Modified script (original: Linwood Creekmore III)

Examples

output to geopandas dataframe (gdf): `gdf = kmx2other("my-places.kmz", output="gpd")`

plot the new gdf (use %matplotlib inline in notebooks) `gdf.plot()`

convert a kml-file to a shapefile `success = kmx2other("my-places.kml", output="shp")`

`flusstools.geotools.kml.`**`kmx2other`**(*file*, *output='df'*)

Converts a Keyhole Markup Language Zipped (KMZ) or KML file to a pandas dataframe, geopandas geodataframe, csv, geojson, or ESRI shapefile.

Parameters

- **`file`** (*`str`*) – The path to a KMZ or KML file.
- **`output`** (*`str`*) – Defines the output type. Valid options are: `"shapefile"`, `"shp"`, `"shapefile"`, or `"ESRI Shapefile"`.

Hint: The core function is taken from http://programmingadvent.blogspot.com/2013/06/kmzkml-file-parsing-with-python.html

Returns

Success message (use `print(kmx2other(...))` to see what the function did.)

Return type
str

Original Classes written by Linwood Creekmore III (modified for flusstools)

Flavored with code blocks from:

- http://programmingadvent.blogspot.com/2013/06/kmzkml-file-parsing-with-python.html
- http://gis.stackexchange.com/questions/159681/geopandas-cant-save-geojson
- https://gist.github.com/mciantyre/32ff2c2d5cd9515c1ee7

`class flusstools.geotools.kmx_parser.`**`ModHTMLParser`**

A child of HTMLParser, tailored (modified) for kml/kmy parsing.

`handle_data`(*data*)

Generates mapping and series if `in_table` is `True`.

Parameters
`data` (*`str`*) – Text lines of data divided by colons.

Returns
Assigns `ModHTMLParser.mapping` and `ModHTMLParser.series` attributes

Return type
None

`handle_starttag`(*tag*, *attrs*)

Enables a table if a table-tag is provided.

Parameters

- **`tag`** (*`str`*) – Set to "table" for enabling usage of a table.
- **`attrs`** (*`list`*) – List of additional attributes (currently unused).

Returns
Verifies if the `tag` argument contains the string `"table"`

Return type
None

`class flusstools.geotools.kmx_parser.`**`PlacemarkHandler`**

Child of `xml.sax.handler.ContentHandler`, tailored for handling kml files.

`characters`(*data*)

Adds a line of data to the read-buffer.

Parameters
`data` (*`str`*) –

Returns
None

`end_element`(*name*)

Sets the end (last) element.

Parameters
`name` (*`str`*) –

Returns
None

htmlizer()

Creates an html file.

Parameters
row (*pandas.df*) – List of strings for conversion

Returns
An instance of the `ModHTMLParser()` class

Return type
htmlparser.series

spatializer()

Converts string objects to spatial Python objects.

Parameters
row (*pandas.df*) – List of strings for conversion

Returns
None

start_element(*name*)

Looks for the first Placemark element in a kml file.

Parameters
name (*str*) – Name-tag of the element

Returns
None

4.3.7 Shortest Path Finder

This module is inspired by Michael Diener - read more at
https://github.com/mdiener21/python-geospatial-analysis-cookbook/tree/master/ch08

Example use: `create_shortest_path(shp_file_name, start_node_id, end_node_id)`

flusstools.geotools.shortest_path.**create_shortest_path**(*line_shp_name*, *start_node_id*, *end_node_id*)

Calculates the shortest path from a network of lines.

Parameters

- **line_shp_name** (*str*) – Input shapefile name
- **start_node_id** (*int*) – Start node ID
- **end_node_id** (*int*) – End node ID

Returns
Creates a graph of nodes (coordinate pairs) connecting a start node with an end node in the defined `line_shp_name`.

Return type
None

flusstools.geotools.shortest_path.**get_full_path**(*path*, *nx_list_subgraph*)

Creates a numpy array of the line result.

Parameters

- **path** (*str*) – Result of `nx.shortest_path`

- **nx_list_subgraph** (*list*) – See `create_shortest path` function

Returns
Coordinate pairs along a path.

Return type
ndarray

`flusstools.geotools.shortest_path.`**`get_path`**(*n0*, *n1*, *nx_list_subgraph*)

Get path between nodes `n0` and `n1`.

Parameters

- **n0** (*int*) – Node 1
- **n1** (*int*) – Node 2
- **nx_list_subgraph** (*list*) – (see create shortest path)

Returns
An array of point coordinates along the line linking these two nodes.

Return type
ndarray

`flusstools.geotools.shortest_path.`**`write_geojson`**(*outfilename*, *indata*)

Creates a new GeoJSON file

Args>
outfilename (str): Name for the output file indata (array): Array to write tyo the geojson file.

Returns
Creates a new GeoJSON file.

CHAPTER

FIVE

FUZZYCORR

FuzzyCorr was developed along with novel fuzzy map comparison methods to evaluate the performance of hydro-morphodynamic numerical models. The procedure and math behind the package are described in Negreiros et al. 2021 (open-access paper) .

Sediment transport and hydraulic processes can be reproduced with numerical models such as SSIIMM, Hydro_AS_2D, TELEMAC and many more. The accuracy of numerical models is assessed through comparing the simulated and the observed datasets, which constitutes a model validation. With the purpose of analyzing simulated and observed bed elevation change, two methods of comparison can be applied:

1. Comparison via statistical methods such as RMSE (Root Mean Squared Error) or visual human comparison. However, local measures of similarity (or a similarity) like the RMSE are very sensible to uncertainty of location and amount, thus indicating low agreement even when overall patterns were adequately simulated.
2. Visual comparison captures global similarity, which is one of the reasons why modelers often use it for model validation. Humans are capable of finding patterns without deliberately trying, and therefore, this type of comparison provides substantial advantages over local similarity measures. Nevertheless, more research has to be done to implement automated validation tools that emulate human thinking. This is necessary because human comparison is not transparent, prone to subjective interpretations, time consuming, and hardly reproducible.

In this context, the concept of fuzzy set theory has capacities to consider similarity of spatial pattern analogous to human thinking. For instance, fuzziness of location introduces a tolerance regarding spatial uncertainty in the results of hydro-morphodynamic models. To this end, fuzzy logic enables an objective validation of such models by overcoming uncertainties in the model structure, parameters and input data.

The algorithms provided with `fuzzycorr` address the necessity in evaluating (or validating) model performance through the use of fuzzy map comparison. Future developments aim to go beyond a one-way validation towards a two-way communication between the validation algorithms and the models. The two-way communication represents a feedback loop that will eventually enable an automated calibration of numerical hydro-morphodynamic models.

5.1 Usage

5.1.1 Basics

The following code block exemplifies the usage of *fuzzycorr* to explore the fuzzy correlation between two (e.g., observed and modeled) maps (in GeoTIFF format):

```
from flusstools import fuzzycorr as fc
```

5.1.2 Example (showcase)

The best way to learn the usage is by examples. In the directory `examples`, the usage of the modules are demonstrated in a case study. Inside the folder `salzach_case`, the results from a hydro-morphodynamic numerical simulation (i.e., simulated bed elevation change, deltaZ) are located in `raw_data`. For more details on the hydro-morphodynamic numerical refer to Beckers et al. (2020).

The following showcase scripts live in *ROOT/examples/fuzzycorr-showcase/*:

- `prepro_salzach.py`: example of the usage of the class `FuzzyPreProcessor` of the module `prepro.py`, where vector data is interpolated and rasterized.
- `classification_salzach.py`: example of the usage of the class `PreProCategorization` of the module `prepro.py`.
- `fuzzycomparison_salzach.py`: example of the usage of the class `FuzzyComparison` of the module `fuzzycomp.py`, which creates a correlation (similarity) measure between simulated and observed datasets.
- `plot_salzach.py`, `plot_class_rasters.py` and `performance_salzach`: example of the usage of the module `plotter.py`.
- `random_map`: example of generating a raster following a uniform random distribution, which uses the module `prepro.py`.

5.2 Structure

This package contains the following modules, which were designed in *Python 3.8*:

- *prepro.py* includes functions for reading, normalizing and rasterizing vector data. These are preprocessing steps for fuzzy map comparison (module fuzzycomp).
- *fuzzycomp.py* provides routines for fuzzy map comparison in continuous valued rasters. Refer to Hagen (2006) for more details.
- *plotter.py*: Visualization routines for output and input rasters.
- The package documentation is located in the folder *docs*.

5.2.1 Pre-processing: prepro.py

Hints:

- many class methods could be imported from geotools
- already removed: clip_raster, which is a duplicate of raster_mgmt

`class flusstools.fuzzycorr.prepro.`**`CategorizationPreProcessor`**(*raster*)

Structured for … (Description to be implemented by Bea)

Parameters
(str) (*raster*) – path of the raster to be categorized

`categorize_raster`(*class_bins*, *map_out*, *save_ascii=True*)

Classifies the raster according to the classification bins

Parameters

- **map_out** – path of the project directory
- **class_bins** – list of floats

- **save_ascii** – bool

Returns
saves the classified raster in the chosen directory

`nb_classes`(*n_classes*)

Generates class bins based on the Natural Breaks method

Parameters
n_classes – integer, number of classes

Returns
list of optimized bins

`class flusstools.fuzzycorr.prepro.FuzzyPreProcessor`(*df*, *attribute*, *crs*, *nodatavalue*, *res=None*, *ulc=(nan, nan)*, *lrc=(nan, nan)*)

Parent pre-processing structure for the comparison of numeric maps

Parameters

- **df** – pandas.DataFrame, can be obtained by reading the textfile as pandas dataframe
- **(str)** (*crs*) – name of the attribute to burn in the raster (ex.: deltaZ, Z)
- **(str)** – coordinate reference system
- **(float)** (*res*) – value to indicate nodata cells
- **(float)** – resolution of the cell (cell size), is the same for x and y
- **ulc** – tuple of floats, upper left corner coordinate, optional
- **lrc** – tuple of floats, lower right corner coordinate, optional

`array2raster`(*array*, *raster_file*, *save_ascii=True*)

Saves a raster using interpolation

Parameters

- **(str)** (*raster_file*) – path to save the rasterfile
- **(bool)** (*save_ascii*) – true to save also an ascii raster

Returns None
Saves the raster with the selected filename

Hint: Function will be moved to `geotools/raster_mgmt` in a future release (operated by Bea)

`create_polygon`(*shape_polygon*, *alpha=nan*)

Creates a polygon surrounding a cloud of shapepoints

Parameters

- **(str)** (*shape_polygon*) – path to save the shapefile
- **(float)** (*alpha*) – excentricity of the alphashape (polygon) to be created

Returns
saves the polygon (*.shp) with the selected filename

Hint: Function can be moved to geotools/shp_mgmt

norm_array(*method='linear'*)

Normalizes the raw data in equally distanced points depending on the selected resolution

Returns
interpolated and normalized array with selected resolution

Hint: Read more at https://github.com/rosskush/skspatial

---

plain_raster(*shapefile*, *raster_file*, *res*)

Converts a shapefile(.shp) to a GeoTIFF raster without normalizing

Parameters

- **(str)** (`raster_file`) – filename with path of the input shapefile (*.shp)
- **(str)** – filename with path of the output raster (*.tif)
- **(float)** (`res`) – resolution of the cell

Returns None
saves the raster in the default directory

points_to_grid()

Creates a grid of new points in the target resolution

Returns
array of size nrow, ncol

Hints:
Read more at http://chris35wills.github.io/gridding_data/

random_raster(*raster_file*, *save_ascii=True*, ***kwargs*)

Creates a raster of randomly generated values

Keyword Arguments
minmax – tuple of floats, (zmin, zmax) min and max ranges for random values

Returns numpy.ndarray
array of random values within a range of the same size and shape as the original

5.2.2 Fuzzy map comparison core: fuzzycomp.py

Head structure for fuzzy map comparisons

Usage: `fuzzy_comparison = FuzzyComparison()`

Descriptions will be updated by Bea

class flusstools.fuzzycorr.fuzzycomp.**FuzzyComparison**(*raster_a*, *raster_b*, *neigh=4*, *halving_distance=2*)

Performing fuzzy map comparison :param raster_a: string, path of the raster to be compared with rasterB :param raster_b: string, path of the raster to be compared with rasterA :param neigh: integer, neighborhood being considered (number of cells from the central cell), default is 4 :param halving_distance: integer, distance (in cells) to which the membership decays to its half, default is 2 `fuzzy_numerical`(*comparison_name*, *save_dir*, *map_of_comparison=True*)

Compares a pair of raster maps using fuzzy numerical spatial comparison

Parameters

- `save_dir` – string, directory where to save the results
- `comparison_name` – string, name of the comparison
- `map_of_comparison` – boolean, create map of comparison in the project directory if True

Returns

Global Fuzzy Similarity and comparison map

`fuzzy_rmse`(*comparison_name*, *save_dir*, *map_of_comparison=True*)

Compares a pair of raster maps using fuzzy root mean square error as spatial comparison

Parameters

- `comparison_name` – string, name of the comparison
- `save_dir` – string, directory where to save the results of the map comparison
- `map_of_comparison` – boolean, if True it creates map of of local squared errors (in the project directory)

Returns

global fuzzy RMSE and comparison map

`get_neighbours`(*array*, *x*, *y*)

Captures the neighbours and their memberships :param array: array A or B :param x: int, cell in x :param y: int, cell in y :return: np.array (float) membership of the neighbours (without mask), np.array (float) neighbours' cells (without mask)

`save_comparison_raster`(*array_local_measures*, *directory*, *file_name*)

Create map of comparison

`save_results`(*measure*, *directory*, *name*)

Saves a results file

`flusstools.fuzzycorr.fuzzycomp.f_similarity`(*centre_cell*, *neighbours*)

Calculates the similarity function for each pair of values (fuzzy numerical method)

Parameters

- `centre_cell` – float, cell under analysis in map A
- `neighbours` – np.array of floats, neighbours in map B

Returns

np.array of floats, each similarity between each of two cells

`flusstools.fuzzycorr.fuzzycomp.squared_error`(*centre_cell*, *neighbours*)

Calculates the error measure fuzzy rmse

Parameters

- `centre_cell` – float, cell under analysis in map A
- `neighbours` – np.array of floats, neighbours in map B

Returns

np.array of floats, each similarity between each of two cells

5.2.3 Plot routines: plotter.py

Plotting routines and classes for fuzzy comparison maps

class flusstools.fuzzycorr.plotter.**RasterDataPlotter**(*path*)

Class of raster for plotting

Parameters
(str) (*path*) – path of the raster to be plotted

make_hist(*legendx*, *legendy*, *fontsize*, *output_file*, *figsize*, *set_ylim=None*, *set_xlim=None*)

Creates a histogram of numerical raster

Parameters

- **(str)** (*output_file*) – legend of the x axis of he histogram
- **(str)** – legend of the y axis of he histogram
- **(int)** (*fontsize*) – size of the font
- **(str)** – path for the output file
- **(tuple)** (*figsize*) – of integers, size of the width x height of the figure
- **(float)** (*set_ylim*) – set the maximum limit of the y axis
- **(float)** – set the maximum limit of the x axis

Returns
saves the figure of the histogram

plot_categorical_raster(*output_file*, *labels*, *cmap*, *box=True*)

Creates a figure of a categorical raster

Parameters

- **output_file** – path, file path of the figure
- **(list)** (*labels*) – of strings, labels (i.e., titles)for the categories
- **(str)** (*cmap*) – colormap to plot the raster
- **box** – boolean, if False it sets off the frame of the picture

Returns
saves the figure of the raster

plot_categorical_w_window(*output_file*, *labels*, *cmap*, *xy*, *width*, *height*, *box=True*)

Creates a figure of a categorical raster with a zoomed window

Parameters

- **(str)** (*cmap*) – file path of the figure
- **(list)** (*labels*) – of strings, labels (i.e., titles)for the categories
- **(str)** – colormap to plot the raster
- **(tuple)** (*xy*) – (x,y), origin of the zoomed window, the upper left corner
- **(int)** (*height*) – width (number of cells) of the zoomed window
- **(int)** – height (number of cells) of the zoomed window

Returns
saves the figure of the raster

plot_continuous_raster(*output_file*, *cmap*, *vmax=nan*, *vmin=nan*, *box=True*)

Creates a figure of a continuous valued raster

Parameters

- **output_file** – path, file path of the figure
- **(str)** (*cmap*) – colormap to plot the raster
- **(float)** (*vmin*) – optional, value maximum of the scale, this value is used in the normalization of the colormap
- **(float)** – optional, value minimum of the scale, this value is used in the normalization of the colormap
- **box** – boolean, if False it sets off the frame of the picture

Returns

saves the figure of the raster

plot_continuous_w_window(*output_file*, *xy*, *width*, *height*, *bounds*, *cmap=None*, *list_colors=None*)

Create a figure of a raster with a zoomed window :param output_file: path, file path of the figure :param xy (tuple): `(x,y)` origin of the zoomed window, the upper left corner :param width (int): width (number of cells) of the zoomed window :param height (int): height (number of cells) of the zoomed window :param bounds (list): of float, limits for each color of the colormap :param cmap (str): optional, colormap to plot the raster :param list_colors (list): of colors (str), optional, as alternative to using a colormap :returns None: saves the figure of the raster

flusstools.fuzzycorr.plotter.**read_raster**(*raster_path*)

Opens a raster using rasterio

Parameters

raster_path (*str*) – directory and name of a raster

Returns

a numpy array of the raster

Return type

`ndarray`

5.3 References

- Ross Kushnereit
- Chris Wills

CHAPTER

SIX

LIDARTOOLS

The *laspy_X* modules are universal *Python3* scripts, which are completely open-source and can be applied on any platform (*Window*, *Linux*). However, *laspy* may crash with larger *las* files (> 1 GB), and in particular, when the available system memory is small. For these reasons, preferably use the inter-platform and open source *laspy_X* modules, but if you need to deal with large *las* files on a weak system, use the *Windows*-only *lastools*. Note that *lastools* builds on LAStools from rapidlasso. It might be possible to run *LAStools* on *Linux* with wine (not yet tested with *flusstools*).

6.1 LasPy

The *laspy_X* modules extract geospatial information from *las* files and convert them to ESRI shapefiles or GeoTIFF rasters. *las* is the typical file format for storing airborne lidar (Light Detection and Ranging) data. The *flusstools laspy_X* modules make use of the inter-platform and open source laspy *Python* package. The currently implemented capacities involve:

- A point shapefile with user-defined point attributes such as *intensity*, *waveform*, or *nir*.
- Digital elevation model (DEM) with user-defined resolution (pixel size).
- *GeoTIFF* rasters with user-defined resolution (pixel size) for any attribute of a *las* file (e.g., *intensity*, *waveform*, or *nir*).

Computation Power and Memory Errors

Las files can be very large and the *laspy_X* modules load entire *las* files in the system memory. A large *las* file (> 1 GB) may result in your system shutting down *Python* because it is *eating* more memory than available. Therefore, consider using *las* file subsets or computers with large memory. Read more about memory errors in the Troubleshooting section (see below **:ref:`memory_error`_**).

6.1.1 Usage

Basics

To convert a *las* file to an ESRI shapefile or GeoTIFF, load *flusstools.lidartools.laspy_main* in Python:

```
import flusstools.lidartools.laspy_main as hylas
las_file_name = "path/to/a/las-file.las"
methods = ["las2shp", "las2tif"]
hylas.process_file(las_file_name, epsg=3857, methods=methods)
```

The above code block defines a `las_file_name` variable and `methods` to be used with `flusstools.lidartools.laspy_main.process_file` (see *Las File Main Script*). The function accepts many more optional arguments:

Loads a las-file and convert it to another geospatial file format (keyword arguments `**opts`).

param source_file_name
Full directory of the source file to use with methods * if method="las2*" > provide a las-file name * if method="shp2*" > provide a shapefile name

type source_file_name
str

param epsg
Authority code to use (try `hylas.lookup_epsg(las_file_name)` to look up the epsg online).

type epsg
int

keyword create_dem
default: False - set to True for creating a digital elevation model (DEM)

kwtype create_dem
bool

keyword extract_attributes
Attributes to extract from the las-file available in pattr (config.py)

kwtype extract_attributes
str

keyword methods
Enabled list strings are las2shp, las2tif, shp2tif, las2dem

kwtype methods
list [*str*]

keyword overwrite
Overwrite existing shapefiles and/or GeoTIFFs (default: `True`).

kwtype overwrite
bool

keyword pixel_size
Use with *2tif to set the size of pixels relative to base units (pixel_size=5 > 5-m pixels)

kwtype pixel_size
float

keyword shapefile_name
Name of the point shapefile to produce with las2*

kwtype shapefile_name
str

keyword tif_prefix
Prefix include folder path to use for GeoTiFFs (defined extract_attributes are appended to file name)

kwtype tif_prefix
str

keyword interpolate_gap_pixels
Fill empty pixels that are not touched by a shapefile point with interpolated values (default: `True`)

kwtype interpolate_gap_pixels
bool

keyword radius1
Define the x-radius for interpolating pixels (default: `-1`, corresponding to infinity). Only applicable `with interpolate_gap_pixels`.

kwtype radius1
float

keyword radius2
Define the y-radius for interpolating pixels (default: `-1`, corresponding to infinity). Only applicable `with interpolate_gap_pixels`.

kwtype radius2
float

keyword power
Power of the function for interpolating pixel values (default: `1.0`, corresponding to linear).

kwtype power
float

keyword smoothing
Smoothing parameter for interpolating pixel values (default: `0.0`).

kwtype smoothing
float

keyword min_points
Minimum number of points to use for interpolation. If the interpolator cannot find at least `min_points` for a pixel, it assigns a `no_data` value to that pixel (default: `0`).

kwtype min_points
int

keyword max_points
Maximum number of points to use for interpolation. The interpolator will not use more than `max_points` closest points to interpolate a pixel value (default: `0`).

kwtype max_points
int

returns
`True` if successful, `False` otherwise

rtype
bool

Note: The `LasPoint` class (see *Las File Main Script*) can also be directly called in any script with `laspy_processor.LasPoint`. Have a look at the `laspy_processor.process_file` function (*Las File Main Script*) to see how an instance of the `LasPoint` class is used.

Application example

The following code block converts a file called *las-example.las* first into a shapefile and then into a *GeoTIFF*. By using the attributes `"aci"`, the `scan_angle` (`a`), the `classification_flags` (`c`), and the `intensity` (`i`) are extracted from the *las* file. Find out more about applicable attributes in the *flusstools.lidartools.laspy_config.wattr* dictionary (see below **:ref:`laspy_config`_**).

```
import flusstools.lidartools.laspy_main as hylas
import os

las_file_name = os.path.abspath("") + "/data/las-example.las"
shp_file_name = os.path.abspath("") + "/data/example.shp"
epsg = 25832
methods = ["las2tif"]
attribs = "aci"
px_size = 2
tif_prefix = os.path.abspath("") + "/data/sub"

hylas.process_file(
     las_file_name,
     epsg=epsg,
     methods=methods,
     extract_attributes=attribs,
     pixel_size=px_size,
     shapefile_name=shp_file_name,
     tif_prefix=tif_prefix
)
```

Note: The method `las2tif` automatically calls the `las2shp` (`flusstools.lidartools.laspy_processor.LasPoint.export2shp`) method because the GeoTIFF pixel values are extracted from the attribute table of the point shapefile. So `las2shp` is the baseline for any other operation.

6.1.2 Code Documentation

Las File Main Script

Main script for las file processing. Use as:

`process_file(source_file_name, epsg, **opts)` (more about arguments in the function doc below)

`flusstools.lidartools.laspy_main.`**`lookup_epsg`**(*file_name*)

Starts a google search to retrieve information from a file name (or other `str`) with information such as *UTM32*.

Parameters

`file_name` (*`str`*) – file name or other string with words separated by "-" or "_"

Notes

- This function opens a google search in the default web browser.
- More information about projections, spatial reference systems, and coordinate systems

  can be obtained with the geo_utils package.

process_file(source_file_name, epsg, **opts)

Loads a las-file and converts it to another geospatial file format (keyword arguments `**opts`).

Note that this function documentation is currently manually implemented because of *Sphinx* having troubles to look behind decorators.

Arguments:

- **source_file_name (`str`): Full directory of the source file to use with methods**
  - if `method="las2*"`: provide a las-file name
  - if `method="shp2*"`: provide a shapefile name
- **epsg** (`int`): Authority code to use (try `hylas.lookup_epsg(las_file_name)` to look up the epsg online).

Keyword Arguments (`**opts`):

- **create_dem** (`bool`): Set to True for creating a digital elevation model (DEM - default: `False`)
- **extract_attributes** (`str`): Attributes to extract from the las-file available in `pattr` (`config.py`)
- **methods** (`list [str]`): Enabled list strings are `las2shp`, `las2tif`, `shp2tif`, `las2dem`.
- **overwrite** (`bool`): Overwrite existing shapefiles and/or GeoTIFFs (default: `True`).
- **pixel_size** (`float`): Use with *2tif to set the size of pixels relative to base units (`pixel_size=5` indicates 5x5-m pixels)
- **shapefile_name** (`str`): Name of the point shapefile to produce with `las2*`
- **tif_prefix** (`str`): Prefix include folder path to use for GeoTiFFs (defined extract_attributes are appended to file name)
- **interpolate_gap_pixels** (`bool`): Fill empty pixels that are not touched by a shapefile point with interpolated values (default: `True`)
- **radius1** (`float`): Define the x-radius for interpolating pixels (default: `-1`, corresponding to infinity). Only applicable `with interpolate_gap_pixels`.
- **radius2** (`float`): Define the y-radius for interpolating pixels (default: `-1`, corresponding to infinity). Only applicable `with interpolate_gap_pixels`.
- **power** (`float`): Power of the function for interpolating pixel values (default: `1.0`, corresponding to linear).
- **smoothing** (`float`): Smoothing parameter for interpolating pixel values (default: `0.0`).
- **min_points** (`int`): Minimum number of points to use for interpolation. If the interpolator cannot find at least `min_points` for a pixel, it assigns a `no_data` value to that pixel (default: `0`).
- **max_points** (`int`): Maximum number of points to use for interpolation. The interpolator will not use more than `max_points` closest points to interpolate a pixel value (default: `0`).

Returns:
bool: True if successful, False otherwise.

More information on pixel value interpolation: * interpolate_gap_pixels=True interpolates values at pixels that are not touched by any las point. * The pixel value interpolation uses gdal_grid (i.e., its Python bindings through gdal.Grid()). * Control the interpolation parameters with the keyword arguments radius1, radius2, power, max_points, min_points, and smoothing.

See also:

All variables are illustratively explained on the GDAL website.

Las Processor

class flusstools.lidartools.laspy_processor.**LasPoint**(*las_file_name*, *epsg=3857*, *use_attributes='aciw'*, *overwrite=True*)

Las file container to convert datasets to ESRI point shapefiles and/or GeoTIFFs.

Parameters

- **las_file_name** (*str*) – Directory to and name of a las file.
- **epsg** (*int*) – Authority Code - Geodetic Parameter Dataset ID (default: 3857).
- **overwrite** (*bool*) – Overwrite existing shapefiles and/or GeoTIFFs (default: True).
- **use_attributes** (*str*) – Attributes (properties) to use from the las-file available in pattr (config.py). (default: use_attributes="aciw").

Variables

- **las_file** (*laspy.file.File*) – A laspy file object
- **attributes** (*str*) – Defined with use_attributes
- **epsg** (*int*) – Authority code
- **gdf** (*geopandas.GeoDataFrame*) – geopandas data frame containing all points of the las file with the properties (columns) defined by use_attributes
- **offset** (*laspy.file.File().header.offset*) – Offset of las points (auto-read)
- **overwrite** (*bool*) – Enable or disable overwriting existing files (default: True)
- **scale** (*laspy.file.File().header.scale*) – Scale of las points relative to the offset (auto-read)
- **shapefile_name** (*str*) – The name and dicrectorty of a point shapefile where all las-file data is stored
- **srs** (*osr.SpatialReference*) – The geo-spatial reference imported from epsg

create_dem(*target_file_name=''*, *pixel_size=1.0*, ***kwargs*)

Creates a digital elevation model (DEM) in GeoTIFF format from the *las* file points.

Parameters

- **target_file_name** (*str*) – A file name including an existing directory where the dem will be created< must end on .tif.
- **pixel_size** (*float*) – The size of one pixel relative to the spatial reference system

Keyword Arguments

- **src_shp_file_name** (*str*) – Name of a shapefile from which elevation information is to be extracted (default: name of the las-point shapefile)
- **elevation_field_name** (*str*) – Name of the field from which elevation data is to be extracted (default: `"elevation"`)
- **interpolate_gap_pixels** (*bool*) – Fill empty pixels that are not touched by a shapefile point with interpolated values (default: `False`)
- **radius1** (*float*) – Define the x-radius for interpolating pixels (default: `-1`, corresponding to infinity). Only applicable `with interpolate_gap_pixels`.
- **radius2** (*float*) – Define the y-radius for interpolating pixels (default: `-1`, corresponding to infinity). Only applicable `with interpolate_gap_pixels`.
- **power** (*float*) – Power of the function for interpolating pixel values (default: `1.0`, corresponding to linear).
- **smoothing** (*float*) – Smoothing parameter for interpolating pixel values (default: `0.0`).
- **min_points** (*int*) – Minimum number of points to use for interpolation. If the interpolator cannot find at least `min_points` for a pixel, it assigns a `no_data` value to that pixel (default: `0`).
- **max_points** (*int*) – Maximum number of points to use for interpolation. The interpolator will not use more than `max_points` closest points to interpolate a pixel value (default: `0`).

Hint: This function works independently and does not require the prior creation of a shapefile.

Returns
`0` if successful, otherwise `-1`

Return type
int

`export2shp(**kwargs)`

Converts las file points to a point shapefile.

Keyword Arguments
shapefile_name (*str*) – Optional shapefile name (must end on .shp). (default: `'/this/dir/las_file_name.shp'`).

Returns
`/path/to/shapefile.shp`, which is a point shapefile created by the function.

Return type
str

`get_file_info()`

Prints las file information to console.

Analysis Configuration

This is the hylas config file

flusstools.lidartools.laspy_config.**pattr = {'C': 'classification', 'G': 'gps_time', 'N': 'num_returns', 'R': 'return_num', 'W': 'waveform_packet_size', 'a': 'scan_angle', 'b': 'blue', 'c': 'classification_flags', 'e': 'edge_flight_line', 'g': 'green', 'i': 'intensity', 'n': 'nir', 'r': 'red', 's': 'scan_dir_flag', 'u': 'user_data', 'w': 'wave_packet_desc_index'}**

`dict` of attributes to extract data layers (shapefile columns or multiple GeoTIFFs) from a las file.

All attributes defined in `pattr.values()` must be an attribute of a las_file object. Print all available las file attributes with:

```
print(dir(LasPoint.las_file))
```

Type
dict

flusstools.lidartools.laspy_config.**wattr = {'C': 'Class', 'G': 'GPStime', 'N': 'NumberRet', 'R': 'ReturnNumber', 'W': 'WaveSize', 'a': 'ScanAngle', 'b': 'Blue', 'c': 'ClassFlag', 'e': 'FlightEdge', 'g': 'Green', 'i': 'Intensity', 'n': 'NIR', 'r': 'Red', 's': 'ScanDir', 'u': 'UserData', 'w': 'WaveformDesc'}**

`dict` with column headers (shapefile attribute table) and GeoTIFF file names to use for parsing attributes.

Type
dict

6.1.3 Troubleshooting

Memory Errors

MemoryError

Cause: *las* files may have a size of several GiB, which may quickly cause a `MemoryError` (e.g., `MemoryError: Unable to allocate 9.1 GiB for an array with shape ...`). In particular, the *Linux* kernel will not attempt to run actions that exceed the commit-able memory.

Solution: Enable memory over-committing:

- **Check the current over-commit mode in *Terminal*:**
  `cat /proc/sys/vm/overcommit_memory`
- If `0` is the answer, the system calculates array dimensions and the required memory (e.g., an array with dimensions `(266838515, 12, 49)` requires a memory of `266838515 * 12 *49 / 1024.0**3` = 146 GiB, which is unlikely to fit in the memory).
- **To enable over-committing, set the commit mode to 1:**
  `echo 1 | sudo tee /proc/sys/vm/overcommit_memory`

Alternative Solution: Use *LasTools* (see below), which has better capacity to deal with system memory limitations, but works on *Windows* only (not yet tested: implementation of *LasTools* in *Linux* with wine).

6.2 LasTools (Windows only)

lastools is forked from GCS_scripts by Kenny Larrieu. The original code is designed for *Python2* and the commercial `arcpy` library. The tweaked codes of *las4windows* run with Python 3.8 and work without `arcpy`. This repository only uses the GUI for lidar processing with LASTools.

Because *LASTools* is proprietary, its executables can hardly be run on Linux or other UNIX-based systems (not yet tested: implementation of *LasTools* in *Linux* with wine). This is why *LasTools* is a *Windows*-only application.

Use the GUI

Launch `flusstools.lidartools.lastools_GUI.create_gui()` to open a graphical user interface that walks you through the *lastools* scripts implemented in *flusstools*, and calls relevant functions by a simple mouse click.

6.2.1 Additional requirements

LASTools is used for LiDAR Data Processing and can be downloaded here.

6.2.2 Usage

The main function to start processing a *las* or *laz* file with *lastools* is `process_lidar`, which can be called as follows:

```
import flusstools.lidartools.lastools_core as lastools

lastools.process_lidar(
    lastoolsdir="C:/dir/to/LAStools/bin",
    lidardir="C:/LiDAR/file/directory",  # las or laz file
    ground_poly="C:/dir/to/Ground-area-shp-file (optional)",  # limit the analysis region
    cores=4,  # numbers of cores to use
    units_code="Meters",  # alternative: "Feet"
    keep_orig_pts=False,  # Keep original ground/veg points (True or False)
    coarse_step="",  # numeric as string (do not use None)
    coarse_bulge="",  # numeric as string (do not use None)
    coarse_spike="",  # numeric as string (do not use None)
    coarse_down_spike="",  # numeric as string (do not use None)
    coarse_offset="",  # numeric as string (do not use None)
    fine_step="",  # numeric as string (do not use None)
    fine_bulge="",  # numeric as string (do not use None)
    fine_spike="",  # numeric as string (do not use None)
    fine_down_spike="",  # numeric as string (do not use None)
    fine_offset=""  # numeric as string (do not use None)
)
```

Alternatively, *lastools* can be started as a graphical user interface as follows (from *Windows Prompt*):

```
cd C:\dir\to\flusstools\lidartools
python LiDAR_processing_GUI
```

6.2.3 Code Documentation

LiDAR processing

Things to consider adding:
choice of las or laz output set default values for lasground_new params clip structures step lasclassify params to identify buildings use veg polygon (if given) instead of inverse ground polygon to clip veg points

class `flusstools.lidartools.lastools_core.`**`DF`**(**args: Any*, ***kwargs: Any*)

Extended pandas DataFrame class with an additional title attribute

`flusstools.lidartools.lastools_core.`**`ar1_acorr`**(*series*, *maxlags=''*)

Returns lag, autocorrelation, and confidence interval using geometric autocorrelation for AR1 fit of series

`flusstools.lidartools.lastools_core.`**`cmd`**(*command*)

Executes command prompt command

`flusstools.lidartools.lastools_core.`**`cox_acorr`**(*series*, *maxlags=''*)

Parameters

- **series** – (list)
- **maxlags** – (str)

Returns
two lists (lags and autocorrelation), using Cox variant 3 of ACF

`flusstools.lidartools.lastools_core.`**`ft`**(*x*, *y*)

Returns the fourier transform magnitude of the x,y data

`flusstools.lidartools.lastools_core.`**`lof_text`**(*pwd*, *src*)

creates a .txt file in pwd (LAStools bin) containing a list of .las/.laz filenames from src directory

`flusstools.lidartools.lastools_core.`**`pd`**(*filename*)

returns point density from lasinfo output .txt file

`flusstools.lidartools.lastools_core.`**`pts`**(*filename*, *lastoolsdir*)

returns number of points in las file

`flusstools.lidartools.lastools_core.`**`r_confidence_interval`**(*r*, *n*, *alpha=0.05*)

Retrieves the confidence interval at the 1-alpha level for correlation of r with n observations when alpha=0.05, it returns the range of possible population correlations at the 95% confidence level so if 0 is not within the bounds, then the correlation is statistically significant at the 95% level

Parameters

- **r** – correlation (float)
- **n** – number of observations (int)
- **alpha** – confidence level (float)

Returns
Confidence interval (low and high) as sequence (list or tuple) of floats.

`flusstools.lidartools.lastools_core.`**`white_noise_acf_ci`**(*series*, *maxlags=''*)

Returns the 95% confidence interval for white noise ACF

File functions

Description

`flusstools.lidartools.lastools_fun.`**`browse`**(*root*, *entry*, *select='file'*, *ftypes=[('All files', '*')]*)

GUI button command opens browser window and adds selected file/folder to entry

`flusstools.lidartools.lastools_fun.`**`get_largest`**(*directory*)

returns name of largest file in directory

`flusstools.lidartools.lastools_fun.`**`get_las_files`**(*directory*)

returns list of all .las/.laz files in directory (at top level)

`flusstools.lidartools.lastools_fun.`**`split_list`**(*list2split*, *break_pts*)

returns list l split up into sublists at break point indices

`flusstools.lidartools.lastools_fun.`**`split_reaches`**(*list_of_reaches*, *new_reach_pts*)

splits l into sections where new_reach_pts contains the starting indices for each slice

CHAPTER SEVEN

CONTRIBUTING

7.1 Become a contributor

Most team members joined in the framework of their Bachelor or Master's Thesis with innovative contributions. So if you are a student and you want to contribute to *flusstools*, why not in the scope of an innovative thesis? Check out our currently open Bachelor and Master Thesis topics.

Obviously you do not have to be a student to join us - please use Sebastian Schwindt s informal contact form - quick response (most of the time) for sure.

7.2 How to document

This package uses *Sphinx* readthedocs and the documentation regenerates automatically after pushing changes to the repositories `main` branch.

To set styles, configure or add extensions to the documentation use `ROOT/.readthedocs.yml` and `ROOT/docs/conf.py`.

Functions and classes are automatically parsed for docstrings and implemented in the documentation. `hylas` docs use google style docstring formats - please familiarize with the style format and strictly apply in all commits.

To modify this documentation file, edit `ROOT/docs/index.rst` (uses reStructuredText format).

In the class or function docstrings use the following section headers:

- `Args` (alias of `Parameters`)
- `Arguments` (alias of `Parameters`)
- `Attention`
- `Attributes`
- `Caution`
- `Danger`
- `Error`
- `Example`
- `Examples`
- `Hint`
- `Important`
- `Keyword Args` (alias of `Keyword Arguments`)

- `Keyword Arguments`
- `Methods`
- `Note`
- `Notes`
- `Other Parameters`
- `Parameters`
- `Return` (alias of `Returns`)
- `Returns`
- `Raise` (alias of `Raises`)
- `Raises`
- `References`
- `See Also`
- `Tip`
- `Todo`
- `Warning`
- `Warnings` (alias of `Warning`)
- `Warn` (alias of `Warns`)
- `Warns`
- `Yield` (alias of `Yields`)
- `Yields`

For local builds of the documentation, the following packages are required:

```
sudo apt-get install build-essential
sudo apt-get install python-dev python-pip python-setuptools
sudo apt-get install libxml2-dev libxslt1-dev zlib1g-dev
apt-cache search libffi
sudo apt-get install -y libffi-dev
sudo apt-get install python3-dev default-libmysqlclient-dev
sudo apt-get install python3-dev
sudo apt-get install redis-server
```

To generate a local html version of the `hylas` documentation, `cd` into the `docs` directory and type:

```
make html
```

Learn more about *Sphinx* documentation and the automatic generation of *Python* code docs through docstrings in the tutorial provided at github.com/sschwindt/docs-with-sphinx.

7.3 Implement new stuff

All contributors, please respect the *Zen of Python* (`import this`).

How to add new package or library imports:

- Add it to the global import management file (*ROOT/import_mgmt.py*) within an *try-except-ImportError* statement (read more).
- If you need to import a library or package that is not yet listed in the *ROOT/environments.yml* and *ROOT/requirements.txt* files, please make sure to add the new library or package in both files.
- Add the new library or package to the `autodoc_mock_imports` *list* in *ROOT/docs/conf.py*.
- Update the version number according to the CONTRIBUTING standards.

Please use *PEP 8* for any code (read more on hydro-informatics.github.io/hypy_pystyle) and try to keep the number of lines per script below 150 (it's hard or even apparently impossible sometimes - just try please).

Important: Only push debugged code to the main branch - Thank you!

CHAPTER

EIGHT

DISCLAIMER AND LICENSE

8.1 Disclaimer (general)

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More information and examples are available in the docs of every *flusstools* module.

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