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Title Bayesian Smoothing of Remote Sensing Image Classification

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Description A Bayesian smoothing method for post-processing of remote sensing image classification which refines the labelling in a classified image in order to enhance its classification accuracy. Combines pixel-based classification methods with a spatial post-processing method to remove outliers and misclassified pixels.

Encoding UTF-8

Language en-US

Depends R (>= 4.1.0)

URL https://github.com/e-sensing/bayesEO/

BugReports https://github.com/e-sensing/bayesEO/issues

License GPL-3

ByteCompile true

Imports dplyr, ggplot2, grDevices, purrr, Rcpp, stars, stats, terra, tibble, tidyr, tmap, yaml

Suggests RcppArmadillo, testthat

LinkingTo Rcpp, RcppArmadillo

RoxygenNote 7.3.2

Collate 'api_check.R' 'bayes_colors.R' 'bayes_label.R' 'bayes_plot.R' 'bayes_read.R' 'bayes_smooth.R' 'bayes_utils.R' 'bayes_variance.R' 'RcppExports.R' 'zzz.R'

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`bayes_colors` *Function to retrieve bayesEO color table*

Description

Returns a color table

Usage

```
bayes_colors()
```

Value

A tibble with color names and values

Author(s)

Gilberto Camara, <gilberto.camara@inpe.br>

bayes_colors_show *Function to show colors in SITS*

Description

Shows the default SITS colors

Usage

```
bayes_colors_show()
```

Value

no return, called for side effects

Author(s)

Gilberto Camara, <gilberto.camara@inpe.br>

bayes_label *Label probability images to create categorical maps*

Description

Takes a classified image with probabilities, and labels the image with the pixel of higher probability

Usage

```
bayes_label(x)
```

Arguments

x	SpatRaster object with probabilities images

Value

A SpatRaster object

Author(s)

Gilberto Camara, <gilberto.camara@inpe.br>

Examples

```
if (bayes_run_examples()) {
    # select a file with probability values
    data_dir <- system.file("/extdata/probs/", package = "bayesEO")
    file <- list.files(data_dir)
    # create a SpatRaster object from the file
    probs_file <- paste0(data_dir, "/", file)
    # provide the labels
    labels <- c("Water", "ClearCut_Burn", "ClearCut_Soil",
             "ClearCut_Veg", "Forest", "Wetland")
    # read the probs file
    probs <- bayes_read_probs(probs_file, labels)
    # produce a labelled map
    map <- bayes_label(probs)
    # plot the labelled map
    bayes_plot_map(map)
}
```

`bayes_plot_hist` *Plot histogram*

Description

Plot histogram

Usage

```
bayes_plot_hist(x, scale = 1, quantile = NULL, sample_size = 15000)
```

Arguments

`x`	SpatRaster to be plotted.
`scale`	Scale factor for SpatRaster
`quantile`	Threshold of values that will be plotted
`sample_size`	Number of samples to extract values

Value

A plot object

Author(s)

Gilberto Camara, <gilberto.camara@inpe.br>

Examples

```
if (bayes_run_examples()) {
    # get the probability file
    data_dir <- system.file("/extdata/probs/", package = "bayesEO")
    file <- list.files(data_dir)
    # read the probability file into a SpatRaster
    x <- terra::rast(paste0(data_dir, "/", file))
    # include the labels
    labels <- c("Water", "ClearCut_Burn", "ClearCut_Soil",
             "ClearCut_Veg", "Forest", "Wetland")
    # associate the labels to the names of the SpatRaster
    names(x) <- labels
    # calculate the variance
    v <- bayes_variance(x)
    # Plot the variance histogram
    bayes_hist(v, quantile = 0.75)
}
```

---

bayes_plot_map *Plot labelled map*

Description

Plot labelled map

Usage

```
bayes_plot_map(
  x,
  legend = NULL,
  palette = "Spectral",
  xmin = NULL,
  xmax = NULL,
  ymin = NULL,
  ymax = NULL,
  tmap_graticules_labels_size = 0.6,
  tmap_legend_title_size = 0.7,
  tmap_legend_text_size = 0.7,
  tmap_legend_bg_color = "white",
  tmap_legend_bg_alpha = 0.5,
  tmap_max_cells = 1e+06
)
```

Arguments

x	SpatRaster to be plotted.
legend	Named vector that associates labels to colors.

palette	A sequential RColorBrewer palette
xmin	Subset to be shown (xmin)
xmax	Subset to be shown (xmax)
ymin	Subset to be shown (ymin)
ymax	Subset to be shown (ymax)
tmap_graticules_labels_size	Size of graticules labels (default: 0.7)
tmap_legend_title_size	Size of legend title (default: 1.5)
tmap_legend_text_size	Size of legend text (default: 1.2)
tmap_legend_bg_color	Color of legend backgound (default: "white")
tmap_legend_bg_alpha	Transparency of legend background (default: 0.5)
tmap_max_cells	Maximum number of cells for tmap (default = 1e+06)

Value

A plot object

Author(s)

Gilberto Camara <gilberto.camara@inpe.br>

Examples

```
if (bayes_run_examples()) {
    # Define location of a probability file
    data_dir <- system.file("/extdata/probs",
                package = "bayesEO")
    # list the file
    file <- list.files(data_dir)
    # build the full path
    probs_file <- paste0(data_dir, "/", file)
    # define labels
    labels <- c("Water", "ClearCut_Burn", "ClearCut_Soil",
                "ClearCut_Veg", "Forest", "Wetland")

    probs_image <- bayes_read_probs(probs_file, labels)
    # Label the probs image
    y <- bayes_label(x)
    # produce a map of the labelled image
    bayes_plot_map(y)
}
```

bayes_plot_probs *Plot probability maps*

Description

Plot probability maps

Usage

```
bayes_plot_probs(
  x,
  scale = 1e-04,
  labels = NULL,
  palette = "YlGnBu",
  tmap_scale = 1
)
```

Arguments

x	SpatRaster to be plotted.
scale	Scaling factor to apply to the data
labels	Labels to be plotted
palette	An RColorBrewer palette
tmap_scale	Global scale parameter for map (default: 1.0)

Value

A plot object

Author(s)

Gilberto Camara, <gilberto.camara@inpe.br>

Examples

```
if (bayes_run_examples()) {
    # get the probability file
    data_dir <- system.file("/extdata/probs/", package = "bayesEO")
    file <- list.files(data_dir)
    # build the full path
    probs_file <- paste0(data_dir, "/", file)
    # include the labels
    labels <- c("Water", "ClearCut_Burn", "ClearCut_Soil",
             "ClearCut_Veg", "Forest", "Wetland")
    # associate the labels to the names of the SpatRaster
    probs <- bayes_read_probs(probs_file, labels)
    # Plot the probability image
```

```
    bayes_plot_probs(probs,
                     scale = 0.0001,
                     tmap_scale = 1.0)
}
```

---

bayes_plot_rgb *Plot RGB data cubes*

Description

Plot RGB raster cube

Usage

```
bayes_plot_rgb(
  image,
  red,
  green,
  blue,
  xmin = NULL,
  xmax = NULL,
  ymin = NULL,
  ymax = NULL
)
```

Arguments

image	Object of class SpatRaster.
red	Band for red color.
green	Band for green color.
blue	Band for blue color.
xmin	Subset to be shown (xmin)
xmax	Subset to be shown (xmax)
ymin	Subset to be shown (ymin)
ymax	Subset to be shown (ymax)

Value

A plot object with an RGB image

Author(s)

Gilberto Camara, <gilberto.camara@inpe.br>

Examples

```
if (bayes_run_examples()) {
# Define location of a RGB files
rgb_dir <- system.file("/extdata/rgb", package = "bayesEO")
# list the file
files <- list.files(rgb_dir)
# build the full path
image_files <- paste0(rgb_dir, "/", files)
rgb_image <- bayes_read_image(image_files)
bayes_plot_rgb(rgb_image, red = "B11", green = "B8A", blue = "B03")
}
```

`bayes_plot_var` *Plot variance maps*

Description

Plot variance maps

Usage

```
bayes_plot_var(
  x,
  labels = NULL,
  quantile = 0.75,
  n = 15,
  style = "equal",
  palette = "YlGnBu",
  tmap_scale = 1
)
```

Arguments

`x`	SpatRaster to be plotted.
`labels`	Labels to be plotted
`quantile`	Thereshold of values to be plotted
`n`	Preferred number of classes
`style`	Method to process the color scale
`palette`	An RColorBrewer palette
`tmap_scale`	Global scale parameter for map (default: 1.5)

Value

A plot object

Author(s)

Gilberto Camara, <gilberto.camara@inpe.br>

Examples

```
if (bayes_run_examples()) {
    # get the probability file
    data_dir <- system.file("/extdata/probs/", package = "bayesEO")
    file <- list.files(data_dir)
    # build the full path
    probs_file <- paste0(data_dir, "/", file)
    # include the labels
    labels <- c("Water", "ClearCut_Burn", "ClearCut_Soil",
             "ClearCut_Veg", "Forest", "Wetland")
    # associate the labels to the names of the SpatRaster
    probs <- bayes_read_probs(probs_file, labels)
    # calculate the variance
    var <- bayes_variance(probs)
    # Plot the variance image
    bayes_plot_var(var,
        n = 15,
        style = "order",
        quantile = 0.75,
        palette = "YlGn",
        labels = c("Forest", "ClearCut_Veg"))
}
```

---

bayes_read_image *Read probability maps*

Description

Read probability maps

Usage

```
bayes_read_image(files)
```

Arguments

files	Full path to raster files

Value

A SpatRaster object

Author(s)

Gilberto Camara, <gilberto.camara@inpe.br>

Examples

```
if (bayes_run_examples()) {
# Define location of a probability file
data_dir <- system.file("/extdata/rgb", package = "bayesEO")
# list the file
files <- list.files(data_dir)
# build the full path
image_files <- paste0(data_dir, "/", files)
rgb_image <- bayes_read_image(image_files)
}
```

---

bayes_read_probs *Read probability maps*

Description

Read probability maps

Usage

```
bayes_read_probs(probs_file, labels)
```

Arguments

probs_file	Full path to raster multi-band file containing probability matrices
labels	Labels to be assigned to the bands

Value

A SpatRaster object

Author(s)

Gilberto Camara, <gilberto.camara@inpe.br>

Examples

```
if (bayes_run_examples()) {
# Define location of a probability file
data_dir <- system.file("/extdata/probs", package = "bayesEO")
# list the file
file <- list.files(data_dir)
# build the full path
probs_file <- paste0(data_dir, "/", file)
# define labels
labels <- c("Water", "ClearCut_Burn", "ClearCut_Soil",
             "ClearCut_Veg", "Forest", "Wetland")

probs_image <- bayes_read_probs(probs_file, labels)
}
```

bayes_run_examples *Informs if examples should run*

Description

This function informs if examples should run. To run the examples, set "BAYES_RUN_EXAMPLES" environment variable to "YES" using Sys.setenv("BAYES_RUN_EXAMPLES" = "YES") To come back to the default behaviour, please unset the enviroment variable Sys.unsetenv("BAYES_RUN_EXAMPLES")

Usage

```
bayes_run_examples()
```

Value

A logical value

bayes_run_tests *Informs if tests should run*

Description

This function informs if tests should run. To run the examples, set "BAYES_RUN_TESTS" environment variable to "YES" using Sys.setenv("BAYES_RUN_TESTS" = "YES") To come back to the default behaviour, please unset the enviroment variable Sys.unsetenv("BAYES_RUN_TESTS")

Usage

```
bayes_run_tests()
```

Value

TRUE/FALSE

bayes_smooth *Smooth probability images*

Description

Takes a classified image with probabilities, and reduces outliers and smoothens probability according to Bayesian statistics

Usage

```
bayes_smooth(x, window_size = 7, neigh_fraction = 0.5, smoothness = 10)
```

Arguments

x	SpatRaster object with probabilities images
window_size	Size of the neighborhood.
neigh_fraction	Fraction of neighbors with high probabilities to be used in Bayesian inference.
smoothness	Estimated variance of logit of class probabilities (Bayesian smoothing parameter). It can be either a vector or a scalar.

Value

A SpatRaster object

Author(s)

Gilberto Camara, <gilberto.camara@inpe.br>

Examples

```
if (bayes_run_examples()) {
    # select a file with probability values
    data_dir <- system.file("/extdata/probs/", package = "bayesEO")
    file <- list.files(data_dir)
    # create a full path for the file
    probs_file <- paste0(data_dir, "/", file)
    # provide the labels
    labels <- c("Water", "ClearCut_Burn", "ClearCut_Soil",
             "ClearCut_Veg", "Forest", "Wetland")
    # read the probs file
    probs <- bayes_read_probs(probs_file, labels)
    # smooth the probability image
    probs_smooth <- bayes_smooth(probs,
            window_size = 7,
            smoothness = 20
    )
    # plot the probability image
    bayes_plot_probs(probs_smooth)
```

```
}
```

`bayes_summary` *Summary of categorical maps*

Description

Takes a classified image with probabilities, and labels the image with the pixel of higher probability

Usage

```
bayes_summary(x, scale = 1, sample_size = 15000)
```

Arguments

`x`	SpatRaster categorical object
`scale`	Scale to apply to data
`sample_size`	Sample size

Value

A tibble with information

Author(s)

Gilberto Camara, <gilberto.camara@inpe.br>

Examples

```
if (bayes_run_examples()) {
    # select a file with probability values
    data_dir <- system.file("/extdata/probs/", package = "bayesEO")
    file <- list.files(data_dir)
    # create a SpatRaster object from the file
    probs_file <- paste0(data_dir, "/", file)
    # provide the labels
    labels <- c("Water", "ClearCut_Burn", "ClearCut_Soil",
             "ClearCut_Veg", "Forest", "Wetland")
    # read the probs file
    probs <- bayes_read_probs(probs_file, labels)
    # produce a labelled map
    map <- bayes_label(probs)
    # plot the labelled map
    bayes_summary(map)
}
```

bayes_variance *Calculate the variance of a probability cube*

Description

Takes a probability cube and estimate the local variance of the logit of the probability, to support the choice of parameters for Bayesian smoothing.

Usage

```
bayes_variance(x, window_size = 9, neigh_fraction = 0.5)
```

Arguments

x	SpatRaster object containing probabilities.
window_size	Size of the neighborhood.
neigh_fraction	Fraction of neighbors with highest probability to be used in Bayesian inference.

Value

A variance SpatRaster object.

Author(s)

Gilberto Camara, <gilberto.camara@inpe.br>

Rolf Simoes, <rolf.simoes@inpe.br>

Examples

```
if (bayes_run_examples()) {
    # select a file with probability values
    data_dir <- system.file("/extdata/probs/", package = "bayesEO")
    file <- list.files(data_dir)
    # create a SpatRaster object from the file
    x <- terra::rast(paste0(data_dir, "/", file))
    # provide the labels
    labels <- c("Water", "ClearCut_Burn", "ClearCut_Soil",
             "ClearCut_Veg", "Forest", "Wetland")
    # name the layers in the SpatRaster with the labels
    names(x) <- labels
    # calculate the variance
    v <- bayes_variance(x)
    # plot the variance
    bayes_plot_var(v, quantile = 0.75)
}
```

`bilateral_smooth` *Smooth probability images with Gaussian filter*

Description

Takes a classified image with probabilities, and reduces outliers and smoothens probability according to a Gaussian filter

Usage

```
bilateral_smooth(x, window_size = 5, sigma = 8, tau = 0.1)
```

Arguments

`x`	SpatRaster object with probabilities images
`window_size`	Size of the neighborhood.
`sigma`	Standard deviation of the spatial Gaussian kernel
`tau`	Standard deviation of the class probs value

Value

A SpatRaster object

Author(s)

Gilberto Camara, <gilberto.camara@inpe.br>

Examples

```
if (bayes_run_examples()) {
    # select a file with probability values
    data_dir <- system.file("/extdata/probs/", package = "bayesEO")
    file <- list.files(data_dir)
    # create a full path for the file
    probs_file <- paste0(data_dir, "/", file)
    # provide the labels
    labels <- c("Water", "ClearCut_Burn", "ClearCut_Soil",
             "ClearCut_Veg", "Forest", "Wetland")
    # read the probs file
    probs <- bayes_read(probs_file, labels)
    # smooth the probability image
    bilat <- bilateral_smooth(probs,
                              window_size = 5,
                              sigma = 8,
                              tau = 0.1
    )
    # plot the probability image
    bayes_plot(bilat, scale = 0.0001)
```

```
}
```

---

gaussian_smooth *Smooth probability images with Gaussian filter*

Description

Takes a classified image with probabilities, and reduces outliers and smoothens probability according to a Gaussian filter

Usage

```
gaussian_smooth(x, window_size = 5, sigma = 1)
```

Arguments

x	SpatRaster object with probabilities images
window_size	Size of the neighborhood.
sigma	Standard deviation of the spatial Gaussian kernel

Value

A SpatRaster object

Author(s)

Gilberto Camara, <gilberto.camara@inpe.br>

Examples

```
if (bayes_run_examples()) {
    # select a file with probability values
    data_dir <- system.file("/extdata/probs/", package = "bayesEO")
    file <- list.files(data_dir)
    # create a full path for the file
    probs_file <- paste0(data_dir, "/", file)
    # provide the labels
    labels <- c("Water", "ClearCut_Burn", "ClearCut_Soil",
             "ClearCut_Veg", "Forest", "Wetland")
    # read the probs file
    probs <- bayes_read(probs_file, labels)
    # smooth the probability image
    gauss <- gaussian_smooth(probs,
            window_size = 5,
            sigma = 1
    )
    # plot the probability image
    bayes_plot_probs(gauss)
```

```
}
```

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