Package ‘CytOpT’

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Type Package

Title Optimal Transport for Gating Transfer in Cytometry Data with Domain Adaptation

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SystemRequirements Python (>= 3.7)

Description Supervised learning from a source distribution (with known segmentation into cell sub-populations) to fit a target distribution with unknown segmentation. It relies regularized optimal transport to directly estimate the different cell population proportions from a biological sample characterized with flow cytometry measurements. It is based on the regularized Wasserstein metric to compare cytometry measurements from different samples, thus accounting for possible mis-alignment of a given cell population across sample (due to technical variability from the technology of measurements). Supervised learning technique based on the Wasserstein metric that is used to estimate an optimal re-weighting of class proportions in a mixture model Details are presented in Freulon P, Bigot J and Hejblum BP (2021) <arXiv:2006.09003>.

Config/reticulate list( packages = list( list(package = "numpy"), list(package = "scikit-learn"), list(package = "scipy")) )

License GPL (>= 2)

Repository CRAN


Depends R (>= 3.6)

LazyData true

RoxygenNote 7.1.2
Function to display a bland plot in order to visually assess the agreement between CytOpt estimation of the class proportions and the estimate of the class proportions provided through manual gating.

Usage

```r
barplot_prop(proportions, title = "", xaxis_angle = 45)
```
**Arguments**

- **proportions** data.frame of (true and) estimated proportions from CytOpt()
- **title** plot title. Default is "", i.e. no title.
- **xaxis_angle** scalar indicating an angle to tilt the labels of x_axis. Default is 45.

**Value**

a ggplot object

**Examples**

```r
if(interactive()){

  res <- CytOpT(X_s = HIPC_Stanford_1228_1A, X_t = HIPC_Stanford_1369_1A,
                 Lab_source = HIPC_Stanford_1228_1A_labels,
                 eps = 0.0001, lbd = 0.0001, n_iter = 10000, n_stoc=10,
                 step_grad = 10, step = 5, power = 0.99,
                 method='minmax')

  barplot_prop(res$proportions)
}
```

---

**Bland_Altman**

*Bland & Altman plot*

**Description**

Function to display a Bland & Altman plot in order to visually assess the agreement between CytOpt estimation of the class proportions and the estimate of the class proportions provided through manual gating. Requires that either theta_true or Lab_target was provided when running CytOpT().

**Usage**

```r
Bland_Altman(proportions, additional_info_shape = NULL)
```

**Arguments**

- **proportions** data.frame of true and estimated proportion returned from CytOpT().
- **additional_info_shape** vector of additional information to be used for shape in the plot. Not implemented yet.

```r
# @return a ggplot object
```

**See Also**

CytOpT
Examples

```r
if(interactive()){

gold_standard_manual_prop <- c(table(HIPC_Stanford_1369_1A_labels) / length(HIPC_Stanford_1369_1A_labels))
res <- CytOpT(X_s = HIPC_Stanford_1228_1A, X_t = HIPC_Stanford_1369_1A,
               Lab_source = HIPC_Stanford_1228_1A_labels,
               theta_true = gold_standard_manual_prop,
               eps = 0.0001, lbd = 0.0001, n_iter = 10000, n_stoc=10,
               step_grad = 10, step = 5, power = 0.99,
               method='both')
Bland_Altman(res$proportions)
}
```

CytOpT

Function to estimate the type cell proportions in an unclassified cytometry data set denoted $X_s$ by using the classification $Lab_{source}$ from an other cytometry data set $X_s$. With this function the computation of the estimate of the class proportions is done with a descent ascent or minmax or two algorithms.

Description

Function to estimate the type cell proportions in an unclassified cytometry data set denoted $X_s$ by using the classification $Lab_{source}$ from an other cytometry data set $X_s$. With this function the computation of the estimate of the class proportions is done with a descent ascent or minmax or two algorithms.

Usage

```r
CytOpT(
  X_s, 
  X_t, 
  Lab_source, 
  Lab_target = NULL, 
  theta_true = NULL, 
  method = c("minmax", "desasc", "both"), 
  eps = 1e-04, 
  n_iter = 10000, 
  power = 0.99, 
  step_grad = 10, 
  step = 5, 
  lbd = 1e-04, 
  n_out = 5000, 
  n_stoc = 10, 
  minMaxScaler = TRUE,
)```
Arguments

X_s  
a cytometry dataframe with only d numerical variables for ns observations. The columns correspond to the different biological markers measured. One line corresponds to the cytometry measurements performed on one cell. The classification of this Cytometry data set must be provided with the Lab_source parameters.

X_t  
a cytometry dataframe with only d numerical variables for nt observations. The columns correspond to the different biological markers measured. One line corresponds to the cytometry measurements performed on one cell. The CytOpT algorithm targets the cell type proportion in this Cytometry data set.

Lab_source  
a vector of length ns Classification of the X_s cytometry data set

Lab_target  
a vector of length nt Classification of the X_s cytometry data set

theta_true  
If available, gold-standard proportions in the target data set X_t derived from manual gating. It allows to assess the gap between the estimate and the gold-standard. Default is NULL, in which case no assessment is performed.

method  
a character string indicating which method to use to compute the cytop, either 'minmax', 'desasc' or 'both' for comparing both Min-max swapping and descent-ascent procedures. Default is 'minmax'.

eps  
a float value of regularization parameter of the Wasserstein distance. Default is 1e-04

n_iter  
an integer Constant that iterate method select. Default is 10000

power  
a float constant the step size policy of the gradient ascent method is step/n^power. Default is 0.99

step_grad  
an integer number step size of the gradient descent algorithm of the outer loop. Default is 10

step  
an integer constant that multiply the step-size policy. Default is 5

lbd  
a float constant that multiply the step-size policy. Default is 1e-04

n_out  
an integer number of iterations in the outer loop. This loop corresponds to the gradient descent algorithm to minimize the regularized Wasserstein distance between the source and target data sets. Default is 1000

n_stoc  
an integer number of iterations in the inner loop. This loop corresponds to the stochastic algorithm that approximates a maximizer of the semi dual problem. Default is 10

minMaxScaler  
a logical flag indicating to whether to scale observations between 0 and 1. Default is TRUE.

monitoring  
a logical flag indicating to possibly monitor the gap between the estimated proportions and the manual gold-standard. Default is FALSE.

thresholding  
a logical flag indicating whether to threshold negative values. Default is TRUE.
Value

a object of class CytOpt, which is a list of two elements:

• proportions a data.frame with the (optionally true and) estimated proportions for each method
• monitoring a list of estimates over the optimization iterations for each method (listed within)

Examples

if(interactive()){

res <- CytOpt(X_s = HIPC_Stanford_1228_1A, X_t = HIPC_Stanford_1369_1A,
             Lab_source = HIPC_Stanford_1228_1A_labels,
             method='minmax')

summary(res)
plot(res)
}

cytopt_desasc_r

Function to estimate the type cell proportions in an unclassified cytometry data set denoted X_s by using the classification Lab_source from an other cytometry data set X_s. With this function the computation of the estimate of the class proportions is done with a descent ascent algorithm.

Description

Function to estimate the type cell proportions in an unclassified cytometry data set denoted X_s by using the classification Lab_source from an other cytometry data set X_s. With this function the computation of the estimate of the class proportions is done with a descent ascent algorithm.

Usage

cytopt_desasc_r(
    X_s, 
    X_t, 
    Lab_source, 
    theta_true = NULL, 
    eps = 1e-04, 
    n_out = 5000, 
    n_stoc = 10, 
    step_grad = 10, 
    monitoring = FALSE
)
Arguments

- **X_s**
a cytometry dataframe. The columns correspond to the different biological markers tracked. One line corresponds to the cytometry measurements performed on one cell. The classification of this Cytometry data set must be provided with the Lab_source parameters.

- **X_t**
a cytometry dataframe. The columns correspond to the different biological markers tracked. One line corresponds to the cytometry measurements performed on one cell. The CytOpT algorithm targets the cell type proportion in this Cytometry data set.

- **Lab_source**
a vector of length \( n \) Classification of the X_s cytometry data set.

- **theta_true**
If available, gold-standard proportions in the target data set \( X_t \) derived from manual gating. It allows to assess the gap between the estimate and the gold-standard. Default is NULL, in which case no assessment is performed.

- **eps**
an float value of regularization parameter of the Wasserstein distance. Default is \( 1e^{-04} \).

- **n_out**
an integer number of iterations in the outer loop. This loop corresponds to the gradient descent algorithm to minimize the regularized Wasserstein distance between the source and target data sets. Default is 5000.

- **n_stoc**
an integer number of iterations in the inner loop. This loop corresponds to the stochastic algorithm that approximates a maximizer of the semi-dual problem. Default is 10.

- **step_grad**
an integer number step size of the gradient descent algorithm of the outer loop. Default is 10.

- **monitoring**
boolean indicating whether Kullback-Leibler divergence should be monitored and store throughout the optimization iterations. Default is FALSE.

Value

A list with the following elements:

- **h_hat**

Description

Function to estimate the type cell proportions in an unclassified cytometry data set denoted \( X_s \) by using the classification Lab_source from an other cytometry data set \( X_s \). With this function an additional regularization parameter on the class proportions enables a faster computation of the estimator.
cytopt_minmax_r

Usage

cytopt_minmax_r(
  X_s,
  X_t,
  Lab_source,
  theta_true = NULL,
  eps = 1e-04,
  lbd = 1e-04,
  n_iter = 10000,
  step = 5,
  power = 0.99,
  monitoring = FALSE
)

Arguments

X_s  Cytometry data set. The columns correspond to the different biological markers tracked. One line corresponds to the cytometry measurements performed on one cell. The classification of this Cytometry data set must be provided with the Lab_source parameter.

X_t  Cytometry data set. The columns correspond to the different biological markers tracked. One line corresponds to the cytometry measurements performed on one cell. The CytOpT algorithm targets the cell type proportion in this Cytometry data set.

Lab_source  Classification of the X_s Cytometry data set

theta_true  If available, gold-standard proportions in the target data set X_t derived from manual gating. It allows to assess the gap between the estimate and the gold-standard. Default is NULL, in which case no assessment is performed.

eps  Regularization parameter of the Wasserstein distance

lbd  an float constant that multiply the step-size policy. Default is 1e-04.

n_iter  an integer Constant that iterate method select. Default is 10000.

step  Constant that multiply the step-size policy. Default is 5.

power  the step size policy of the gradient ascent method is step/n^power. Default is 0.99.

monitoring  boolean indicating whether Kullback-Leibler divergence should be monitored and store throughout the optimization iterations. Default is FALSE.

Value

A list with the following elements: Results_Minmax
Description

HIPC T cell data set from HIPC program for patients 1228 and 1369 (replicate 1A from Stanford).

Usage

data(HIPC_Stanford)

Format

The data are composed of 4 objects:

HIPC_Stanford_1228_1A: a data.frame of 31342 cells and 7 markers.
HIPC_Stanford_1228_1A_labels: a factor vector with the cell type of each of the 31342 observed cells.
HIPC_Stanford_1369_1A: a data.frame of 33992 cells and 7 markers.
HIPC_Stanford_1369_1A_labels: a factor vector with the cell type of each of the 33992 observed cells.

Details

This immunophenotyping T cell panel from the Lyoplate HIPC dataset was used as part of the FlowCAP III Lyoplate challenge.

Flow cytometry data set from the HIPC T-cell panel study. In the HIPC T-cell panel study, Flow cytometry was measured in 3 samples for each 3 patients (IDs: 1228, 1349 and 1369) with 3 replicates each (1A, 2B and 3C) in 7 centers (NHLBI, Yale, UCLA, CIMR, Baylor, Stanford and Miami), i.e. 63 data sets in total. Manual gating was performed in the different centers to cluster the observed cells into one of 10 cellular populations:

1. CD8 Effector
2. CD8 Naive
3. CD8 Central Memory
4. CD8 Effector Memory
5. CD8 Activated
6. CD4 Effector
7. CD4 Naive
8. CD4 Central Memory
9. CD4 Effector Memory
10. CD4 Activated
**KL_plot**

**Source**


**References**


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**KL_plot**  
*Kullback-Leibler divergence plot*

**Description**

A plotting function for displaying Kullback-Liebler (KL) divergence across iterations of the optimization algorithm(s).

**Usage**

```
KL_plot(
  monitoring,
  n_0 = 10,
  n_stop = 1000,
  title = "Kullback-Liebler divergence trace"
)
```

**Arguments**

- `monitoring`: list of monitoring estimates from CytOpt() output.
- `n_0`: first iteration to plot. Default is 10.
- `n_stop`: last iteration to plot. Default is 1000.
- `title`: plot title. Default is "Kullback-Liebler divergence trace".

**Value**

a *ggplot* object
Examples

if(interactive()){

gold_standard_manual_prop <- c(table(HIPC_Stanford_1369_1A_labels) / 
length(HIPC_Stanford_1369_1A_labels))
res <- CytOpT(X_s = HIPC_Stanford_1228_1A, X_t = HIPC_Stanford_1369_1A, 
             Lab_source = HIPC_Stanford_1228_1A_labels, 
             theta_true = gold_standard_manual_prop, 
             eps = 0.0001, lbd = 0.0001, n_iter = 10000, n_stoc=10, 
             step_grad = 10, step = 5, power = 0.99, 
             method='both', monitoring = TRUE)
plot(res)
}

Label_Prop_sto_r

Computes a classification on the target data

Description

Computes a classification on the target data thanks to the approximation of the transport plan and 
the classification of the source data. Transport plan is approximated with the stochastic algorithm.

Usage

Label_Prop_sto_r(
    X_s,
    X_t,
    Lab_source,
    eps = 1e-04,
    const = 0.1,
    n_iter = 4000,
    minMaxScaler = TRUE,
    monitoring = TRUE,
    thresholding = TRUE
)

Arguments

X_s a cytometry dataframe. The columns correspond to the different biological 
markers tracked. One line corresponds to the cytometry measurements performed on one cell. The classification of this Cytometry data set must be provided with the Lab_source parameters.

X_t a cytometry dataframe. The columns correspond to the different biological 
markers tracked. One line corresponds to the cytometry measurements performed on one cell. The CytOpT algorithm targets the cell type proportion in this Cytometry data set.
Lab_source  a vector of length \( n \) Classification of the \( X_s \) cytometry data set
eps  an float value of regularization parameter of the Wasserstein distance. Default is \( 1e^{-04} \)
const  an float constant. Default is \( 1e^{-01} \)
n_iter  an integer Constant that iterate method select. Default is 4000
minMaxScaler  a logical flag indicating to possibly Scaler
monitoring  a logical flag indicating to possibly monitor the gap between the estimated proportions and the manual gold-standard. Default is FALSE
thresholding  a logical flag.

Value

a \texttt{ggplot} object

a vector of length \( \text{nrow}(X_t) \) with the propagated labels

Examples

if(interactive()){
  res <- Label_Prop_sto_r(X_s = HIPC_Stanford_1228_1A, X_t = HIPC_Stanford_1369_1A,
                         Lab_source = HIPC_Stanford_1228_1A_labels)
}

plot.CytOpt

\textit{CytOpt} plot

Description

plot S3 method for CytOpt object

Usage

## S3 method for class 'CytOpt'
plot(x, ...)

Arguments

x  an object of class CytOpt to plot.

...  further arguments passed to or from other methods. Not implemented.

Value

a \texttt{ggplot} object, potentially composed through \texttt{patchwork}
Examples

```r
if(interactive()){  
  res <- CytOpT(X_s = HIPC_Stanford_1228_1A, X_t = HIPC_Stanford_1369_1A,  
                 Lab_source = HIPC_Stanford_1228_1A_labels,  
                 eps = 0.0001, lbd = 0.0001, n_iter = 10000, n_stoc=10,  
                 step_grad = 10, step = 5, power = 0.99,  
                 method='minmax')
  plot(res)
  print(res)
}
```

Description

`print.CytOpt` is the S3 method for `CytOpt` object.

Usage

```r
## S3 method for class 'CytOpt'
print(x, ...)  
```

Arguments

- `x`: an object of class `CytOpt` to print.
- `...`: further arguments passed to or from other methods. Not implemented.

Value

The proportions data.frame from `x`.

Examples

```r
if(interactive()){  
  res <- CytOpT(X_s = HIPC_Stanford_1228_1A, X_t = HIPC_Stanford_1369_1A,  
                 Lab_source = HIPC_Stanford_1228_1A_labels,  
                 eps = 0.0001, lbd = 0.0001, n_iter = 10000, n_stoc=10,  
                 step_grad = 10, step = 5, power = 0.99,  
                 method='minmax')
  print(res)
}
```
print.summary.CytOpt  

CytOpt print summary

Description

print S3 method for summary.CytOpt object

Usage

## S3 method for class 'summary.CytOpt'
print(x, ...)

Arguments

x  
an object of class summary.CytOpt to print.

...  
further arguments passed to or from other methods. Not implemented.

Value

a list object

summary.CytOpt  

CytOpt summary

Description

summary S3 method for CytOpt object

Usage

## S3 method for class 'CytOpt'
summary(object, ...)

Arguments

object  
an object of class CytOpt to summarized.

...  
further arguments passed to or from other methods. Not implemented.

Value

a list object
Examples

if(interactive()){

res <- CytOpT(X_s = HIPC_Stanford_1228_1A, X_t = HIPC_Stanford_1369_1A,
              Lab_source = HIPC_Stanford_1228_1A_labels,
              eps = 0.0001, lbd = 0.0001, n_iter = 10000, n_stoc=10,
              step_grad = 10, step = 5, power = 0.99,
              method='minmax', monitoring=TRUE)

summary(res)

}
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