

# Package ‘HistDAWass’

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**Type** Package

**Title** Histogram-Valued Data Analysis

**Version** 1.0.3

**Date** 2019-06-04

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**Description** In the framework of Symbolic Data Analysis, a relatively new approach to the statistical analysis of multi-valued data, we consider histogram-valued data, i.e., data described by univariate histograms. The methods and the basic statistics for histogram-valued data are mainly based on the L2 Wasserstein metric between distributions, i.e., the Euclidean metric between quantile functions. The package contains unsupervised classification techniques, least square regression and tools for histogram-valued data and for histogram time series. An introducing paper is Irpino A. Verde R. (2015) <doi:10.1007/s11634-014-0176-4>.

**License** GPL (>= 2)

**Imports** graphics, class, FactoMineR, ggplot2, ggridges, grid, histogram, grDevices, stats, utils, Rcpp

**Depends** R(>= 3.1), methods

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HistDAWass-package      *Histogram-Valued Data Analysis*

---

## Description

We consider histogram-valued data, i.e., data described by univariate histograms. The methods and the basic statistics for histogram-valued data are mainly based on the L2 Wasserstein metric between distributions, i.e., a Euclidean metric between quantile functions. The package contains unsupervised classification techniques, least square regression and tools for histogram-valued data and for histogram time series.

## Details

Package: HistDAWass  
 Type: Package  
 Version: 0.1.1  
 Date: 2014-09-17  
 License: GPL (>=2)  
 Depends: methods

~~ An overview of how to use the package, including the most important functions ~~

## Author(s)

Antonio Irpino <antonio.irpino@unicampania.it>

## References

Irpino, A., Verde, R. (2015) *Basic statistics for distributional symbolic variables: a new metric-based approach*, Advances in Data Analysis and Classification, Volume 9, Issue 2, pp 143–175. DOI <https://doi.org/10.1007/s11634-014-0176-4>

## Examples

```
# Generating a list of distributions
a<-vector("list",4)
a[[1]]<-distributionH(x=c(80,100,120,135,150,165,180,200,240),
  p=c(0,0.025,0.1,0.275,0.525,0.725,0.887,0.975,1))
a[[2]]<-distributionH(x=c(80,100,120,135,150,165,180,195,210,240),
  p=c(0,0.013,0.101,0.255,0.508,0.718,0.895,0.961,0.987,1))
a[[3]]<-distributionH(x=c(95,110,125,140,155,170,185,200,215,230,245),
  p=c(0,0.012,0.041,0.154,0.36,0.595,0.781,0.929,0.972,0.992,1))
a[[4]]<-distributionH(x=c(105,120,135,150,165,180,195,210,225,240,260),
  p=c(0,0.009,0.035,0.081,0.186,0.385,0.633,0.832,0.932,0.977,1))
```

```

# Generating a list of names of observations
namerows<-list( 'u1' , 'u2')
# Generating a list of names of variables
namevars<-list( 'Var_1' , 'Var_2')
# creating the Math
Mat_of_distributions<-Math(x=a, nrows = 2, ncols = 2,
                           rownames=namerows, varnames=namevars, by.row=FALSE )

```

\*-methods

*Method \****Description**

the product of a number and a distribution according to the L2 Wasssertein  
the product of a number and a distribution according to the L2 Wasssertein  
the product of a number and a distribution according to the L2 Wasssertein

**Usage**

```

## S4 method for signature 'distributionH,distributionH'
e1 * e2

## S4 method for signature 'numeric,distributionH'
e1 * e2

## S4 method for signature 'distributionH,numeric'
e1 * e2

```

**Arguments**

e1                    a distributionH object or a number  
e2                    a distributionH object or a number

+

*Method +***Description**

the sum of two distribution according to the L2 Wasssertein  
the sum of a number and a distribution according to the L2 Wasssertein  
the sum of adistribution and a number according to the L2 Wasssertein

**Usage**

```
## S4 method for signature 'distributionH,distributionH'  
e1 + e2  
  
## S4 method for signature 'numeric,distributionH'  
e1 + e2  
  
## S4 method for signature 'distributionH,numeric'  
e1 + e2
```

**Arguments**

e1                    a distributionH object or a number  
e2                    a distributionH object or a number

**Value**

a distributionH object

---

Age\_Pyramids\_2014      *Age pyramids of all the countries of the World in 2014*

---

**Description**

The dataset contains a MatH (matrix of histogram-valued data) object, with three histogram-valued variables, the 5-years age (relative frequencies) distribution of all the population, of the male and of the female population of 228 countries of the World. The first row is the World data. Thus it contains 229 rows(228 countries plus the World) and 3 variables: "Both.Sexes.Population", "Male.Population", "Female.Population"

**Format**

a MatH object, a matrix of distributions.

**Author(s)**

Antonio Irpino, 2014-10-05

**Source**

United States Census Bureau <https://www.census.gov/data.html>

---

Agronomique

*Agronomique data*

---

**Description**

A dataset with the distributions of marginal costs of farms in 22 France regions. It contains four histogram variables: "Y\_TSC" (Total costs of a farm), "X\_Wheat" (Costs for Wheat), "X\_Pig" (Costs for Pigs) "X\_Cmilk" (Costs for Cow Milk)

**Format**

a MatH object, a matrix of distributions.

**Author(s)**

Antonio Irpino, 2014-10-05

**Source**

Rosanna Verde, Antonio Irpino, Second University of Naples; Dominique Desbois, UMR Economie publique, INRA-AgroParisTech, How to cope with modelling and privacy concerns? A regression model and a visualization tool for aggregated data, Conference of European Statistics Stakeholders, Rome, November, 24-25,2014

---

BLOOD

*Blood dataset for Histogram data analysis*

---

**Description**

The dataset contains a MatH (matrix of histogram-valued data) object This data set list 14 groups of patients described by 3 variables.

**Format**

a MatH instance, 1 row per group.

**Author(s)**

Antonio Irpino, 2014-10-05

**Source**

Billard L. and Diday E. (2006). Symbolic Data Analysis: Conceptual Statistics and Data Mining, Wiley.

---

 BloodBRITO

*Blood dataset from Brito P. for Histogram data analysis*


---

**Description**

The dataset contains a Math (matrix of histogram-valued data) object This data set list 10 patients described by 2 variables.

**Format**

a Math instance, 1 row per patient.

**Author(s)**

Antonio Irpino, 2014-10-05

**Source**

Dias, S. and Brito P. Distribution and Symmetric Distribution Regression Model for Histogram-Valued Variables, ArXiv, arXiv:1303.6199 [stat.ME]

---

 Center.cell.Math

*Method Center.cell.Math Centers all the cells of a matrix of distributions*


---

**Description**

The function transform a Math object (i.e. a matrix of distributions), such that each distribution is shifted and has a mean equal to zero

**Usage**

```
Center.cell.Math(object)
```

```
## S4 method for signature 'Math'
```

```
Center.cell.Math(object)
```

**Arguments**

object            a Math object, a matrix of distributions.

**Value**

A Math object, having each distribution with a zero mean.



**Examples**

```
CEN_BLOOD=Center.cell.Math(BLOOD)
get.Math.stats(BLOOD, stat="mean")
```

---

checkEmptyBins	<i>Method</i> checkEmptyBins
----------------	------------------------------

---

**Description**

The method checking for empty bins in a distribution, i.e. if two cdf consecutive values are equal. In that case a probability value of  $1e-7$  is assigned to the empty bin and the cdf is recomputed. This methods is useful for numerical reasons.

**Usage**

```
checkEmptyBins(object)

## S4 method for signature 'distributionH'
checkEmptyBins(object)
```

**Arguments**

object            a distributionH object

**Value**

A distributionH object without empty bins

**Author(s)**

Antonio Irpino

**Examples**

```
##---- A mydist distribution with an empty bin i.e. two consecutive values of p are equal----
mydist<-distributionH(x=c(1,2,3,10), p=c(0,0.5,0.5,1))
##---- Checks for empty byns and returns the newdist object without empty bins ----
newdist<-checkEmptyBins(mydist)
```

---

China\_Month

*A monthly climatic dataset of China*

---

### **Description**

A dataset with the distributions of some climatic variables collected for each month in 60 stations of China. The collected variables are 168 i.e. 14 climatic variables observed for 12 months. The 14 variables are the following: mean station pressure (mb), mean temperature, mean maximum temperature, mean minimum temperature, total precipitation (mm), sunshine duration (h), mean cloud amount (percentage of sky cover), mean relative humidity ( mean wind speed (m/s), dominant wind frequency ( extreme minimum temperature. Use the command `get.Math.main.info(China_Month)` for rapid info.

### **Format**

a MatH object, a matrix of distributions.

### **Author(s)**

Antonio Irpino, 2014-10-05

### **Source**

raw data are available here: <http://cdiac.ess-dive.lbl.gov/ftp/tr055/>

---

China\_Seas

*A seasonal climatic dataset of China*

---

### **Description**

A dataset with the distributions of some climatic variables collected for each season in 60 stations of China. The collected variables are 56 i.e. 14 climatic variables observed for 4 seasons. The 14 variables are the following: mean station pressure (mb), mean temperature, mean maximum temperature, mean minimum temperature, total precipitation (mm), sunshine duration (h), mean cloud amount (percentage of sky cover), mean relative humidity ( mean wind speed (m/s), dominant wind frequency ( extreme minimum temperature. Use the command `get.Math.main.info(China_Seas)` for rapid info.

### **Format**

a MatH object, a matrix of distributions.

### **Author(s)**

Antonio Irpino, 2014-10-05

**Source**

raw data are available here: <http://cdiac.ess-dive.lbl.gov/ftp/tr055/>. Climate Data Bases of the People's Republic of China 1841-1988 (TR055) DOI: 10.3334/CDIAC/cli.tr055

---

compP	<i>Method compP</i>
-------	---------------------

---

**Description**

Compute the cdf probability at a given value for a histogram

**Usage**

```
compP(object, q)
```

```
## S4 method for signature 'distributionH,numeric'  
compP(object, q)
```

**Arguments**

object	is an object of distributionH class
q	is a numeric value

**Value**

Returns a value between 0 and 1.

**Examples**

```
##---- A mydist distribution ----  
mydist<-distributionH(x=c(1,2,3,10), p=c(0,0.1,0.5,1))  
##---- Compute the cfd value for q=5 (not observed) ----  
p<-compP(mydist,5)
```

---

 compQ

 Method compQ
 

---

**Description**

Compute the quantile value of a histogram for a given probability.

**Usage**

```
compQ(object, p)
```

```
## S4 method for signature 'distributionH,numeric'
compQ(object, p)
```

**Arguments**

object	an object of distributionH class
p	a number between 0 and 1

**Value**

$$y = F^{-1}(p) = Q(p)$$

A number that is the quantile of the passed histogram object at level p.

**Author(s)**

Antonio Irpino

**Examples**

```
##---- A mydist distribution ----
mydist<-distributionH(x=c(1,2,3,10), p=c(0,0.1,0.5,1))
##---- Compute the quantile of mydist for different values of p ----
y<-compQ(mydist,0.5) #the median
y<-compQ(mydist,0) #the minimum
y<-compQ(mydist,1) #the maximum
y<-compQ(mydist,0.25) #the first quartile
y<-compQ(mydist,0.9) #the ninth decile
```

---

crwtransform	<i>Method crwtransform: returns the centers and the radii of bins of a distribution</i>
--------------	---

---

### Description

Centers and ranges calculation for bins of a histogram. It is useful for a very fast computation of statistics and methods based on the L2 Wasserstein distance between histograms.

### Usage

```
crwtransform(object)
```

```
## S4 method for signature 'distributionH'
crwtransform(object)
```

### Arguments

object            a distributionH object

### Value

A list containing

\$Centers	The midpoints of the bins of the histogram
\$Radii	The half-lengths of the bins of the histogram
\$Weights	The relative frequencies or the probabilities associated with each bin (the sum is equal to 1)

### Author(s)

Antonio Irpino

### References

Irpino, A., Verde, R., Lechevallier, Y. (2006) *Dynamic clustering of histograms using Wasserstein metric*, In: Proceedings of COMPSTAT 2006, Physica-Verlag, 869-876

### Examples

```
##---- A mydist distribution ----
mydist<-distributionH(x=c(1,2,3,10), p=c(0,0.1,0.5,1))
##---- Compute the cfd value for q=5 (not observed) ----
crwtransform(mydist)
```

---

 data2hist
 

---



---

*From real data to distributionH.*


---

### Description

From real data to distributionH.

### Usage

```
data2hist(data, algo = "histogram", type = "combined", qua = 10,
           breaks = numeric(0), epsilon = 0.01)
```

### Arguments

data	a set of numeric values.
algo	(optional) a string. Default is "histogram", i.e. the function "histogram" defined in the <a href="#">histogram</a> package. If "base" the <a href="#">hist</a> function is used. "FixedQuantiles" computes the histogram using as breaks a fixed number of quantiles. "ManualBreaks" computes a histogram where braks are provided as a vector of values. "PolyLine" computes a histogram using a piecewise linear approximation of the empirical cumulative distribution function using the "Ramer-Douglas-Peucker algorithm", <a href="http://en.wikipedia.org/wiki/Ramer-Douglas-Peucker_algorithm">http://en.wikipedia.org/wiki/Ramer-Douglas-Peucker_algorithm</a> . An epsilon parameter is required. The data are scaled in order to have a standard deviation equal to one.
type	(optional) a string. Default is "combined" and generates a histogram having regularly spaced breaks (i.e., equi-width bins) and irregularly spaced ones. The choice is done accordingly with the penalization method described in <a href="#">histogram</a> . "regular" returns equi-width binned histograms, "irregular" returns a histogram without equi-width histograms.
qua	a positive integer to provide if algo="FixedQuantiles" is chosen. Default=10.
breaks	a vector of values to provide if algo="ManualBreaks" is chosen.
epsilon	a number between 0 and 1 to provide if algo="PolyLine" is chosen. Default=0.01.

### Value

A distributionH object, i.e. a distribution.

### See Also

[histogram](#) function

**Examples**

```
data=rnorm(n = 1000,mean = 2,sd = 3)
mydist=data2hist(data)
plot(mydist)
```

---

distributionH-class    *Class distributionH.*

---

**Description**

Class "distributionH" defines an histogram object. The class describes a histogram by means of its cumulative distribution function. The methods are developed accordingly to the L2 Wasserstein distance between distributions.

A histogram object can be created also with the function `distributionH(...)`, the constructor function for creating an object containing the description of a histogram.

**Usage**

```
## S4 method for signature 'distributionH'
initialize(.Object, x = numeric(),
          p = numeric(), m = numeric(), s = numeric())

distributionH(x = numeric(), p = numeric())
```

**Arguments**

<code>.Object</code>	the type ("distributionH")
<code>x</code>	a numeric vector. it is the domain of the distribution (i.e. the extremes of bins).
<code>p</code>	a numeric vector (of the same length of <code>x</code> ). It is the cumulative distribution function CDF.
<code>m</code>	(optional) a numeric value. Is the mean of the histogram.
<code>s</code>	(optional) a numeric positive value. It is the standard deviation of a histogram.

**Details**

Class `distributionH` defines a histogram object

**Value**

A `distributionH` object

**Objects from the Class**

Objects can be created by calls of the form `new("distributionH", x, p, m, s)`.

**Author(s)**

Antonio Irpino

**References**

Irpino, A., Verde, R. (2015) *Basic statistics for distributional symbolic variables: a new metric-based approach* Advances in Data Analysis and Classification, DOI 10.1007/s11634-014-0176-4

**See Also**

[meanH](#) computes the mean. [stdH](#) computes the standard deviation.

**Examples**

```
#---- initialize a distributionH object mydist
# from a simple histogram
# -----
# | Bins    | Prob  | cdf   |
# -----
# | [1,2)  | 0.4   | 0.4   |
# | [2,3]  | 0.6   | 1.0   |
# -----
# | Tot.   | 1.0   | -     |
# -----
mydist=new("distributionH",c(1,2,3),c(0, 0.4, 1))
str(mydist)
# OUTPUT
# Formal class 'distributionH' [package "HistDAWass"] with 4 slots
# ..@ x: num [1:3] 1 2 3 the quantiles
# ..@ p: num [1:3] 0 0.4 1 the cdf
# ..@ m: num 2.1 the mean
# ..@ s: num 0.569 the standard deviation
# or using
mydist=distributionH(x=c(1,2,3),p=c(0,0.4, 1))
```

---

dotpW

*Method* dotpW

---

**Description**

The dot product of two distributions inducing the L2 Wasserstein metric

The dot product of a number (considered as an impulse distribution function) and a distribution

The dot product of a distribution and a number (considered as an impulse distribution function).



**Usage**

```
dotpW(e1, e2)

## S4 method for signature 'distributionH,distributionH'
dotpW(e1, e2)

## S4 method for signature 'numeric,distributionH'
dotpW(e1, e2)

## S4 method for signature 'distributionH,numeric'
dotpW(e1, e2)
```

**Arguments**

e1	a distributionH object or a number
e2	a distributionH object or a number

**Value**

A numeric value

**Author(s)**

Antonio Irpino

**References**

Irpino, A., Verde, R. (2015) *Basic statistics for distributional symbolic variables: a new metric-based approach* Advances in Data Analysis and Classification, DOI 10.1007/s11634-014-0176-4

**Examples**

```
## let's define two distributionH objects
mydist1<-distributionH(x=c(1,2,3,10), p=c(0,0.1,0.5,1))
mydist2<-distributionH(x=c(5,7,15), p=c(0,0.7,1))

## the dot product between the distributions
dotpW(mydist1,mydist2) #---> 39.51429

## the dot product between a distribution and a numeric
dotpW(mydist1,3) #---> 13.2
dotpW(3,mydist1) #---> 13.2
```

---

DouglasPeucker	<i>Ramer-Douglas-Peucker algorithm for curve fitting with a PolyLine</i>
----------------	--

---

**Description**

Ramer-Douglas-Peucker algorithm for curve fitting with a PolyLine

**Usage**

```
DouglasPeucker(points, epsilon)
```

**Arguments**

points	a 2D matrix with the coordinates of 2D points
epsilon	an number between 0 and 1. Recomend 0.01.

**Value**

A matrix with the points of segments of a Poly Line.

**See Also**

[data2hist](#) function

---

get.cell.Math	<i>Method get.cell.Math Returns the histogram in a cell of a matrix of distributions</i>
---------------	--

---

**Description**

Returns the histogram data in the r-th row and the c-th column.

**Usage**

```
get.cell.Math(object, r, c)
```

```
## S4 method for signature 'Math,numeric,numeric'  
get.cell.Math(object, r, c)
```

**Arguments**

object	a Math object, a matrix of distributions.
r	an integer, the row index.
c	an integer, the column index

**Value**

A distributionH object.

**Examples**

```
get.cell.Math(BLOOD, r=1,c=1)
```

---

get.distr                    *Method get.distr: show the distribution*

---

**Description**

This function return the cumulative distribution function of a distributionH object.

**Usage**

```
get.distr(object)  
  
## S4 method for signature 'distributionH'  
get.distr(object)
```

**Arguments**

object                    a distributionH object.

**Value**

A data frame: the first column contains the domain the second the CDF values.

**Examples**

```
D=distributionH(x=c(1,2,3,4),p=c(0,0.2,0.6, 1))  
get.distr(D) #a data.frame describing the CDF of D
```

---

get.histo                    *Method get.histo: show the distribution with bins*

---

**Description**

This function return a data.frame describing the histogram of a distributionH object.

**Usage**

```
get.histo(object)  
  
## S4 method for signature 'distributionH'  
get.histo(object)
```

**Arguments**

object            a distributionH object.

**Value**

A matrix: the two columns contains the bounds of the histogram the third contains the probability (or the relative frequency) of the bin.

**Examples**

```
D=distributionH(x=c(1,2,3,4),p=c(0,0.2,0.6, 1))
get.histo(D) #returns the histogram representation of D by a data.frame
```

---

get.m

*Method get.m: the mean of a distribution*

---

**Description**

This function return the mean of a distributionH object.

**Usage**

```
get.m(object)
```

```
## S4 method for signature 'distributionH'
get.m(object)
```

**Arguments**

object            a distributionH object

**Value**

A numeric value

**Examples**

```
D=distributionH(x=c(1,2,3,4),p=c(0,0.2,0.6, 1))
get.m(D) #returns the mean of D
```

---

```
get.Math.main.info      Method get.Math.main.info
```

---

**Description**

It returns the number of rows, of columns the labels of rows and columns of a Math object.

**Usage**

```
get.Math.main.info(object)

## S4 method for signature 'Math'
get.Math.main.info(object)
```

**Arguments**

object            a Math object

**Value**

A list of char, the labels of the columns, or the names of the variables.

**Slots**

```
nrows - the number of rows
ncols - the number of columns
rownames - a vector of char, the names of rows
varnames - a vector of char, the names of columns
```

---

```
get.Math.ncols      Method get.Math.ncols
```

---

**Description**

It returns the number of columns of a Math object

**Usage**

```
get.Math.ncols(object)

## S4 method for signature 'Math'
get.Math.ncols(object)
```

**Arguments**

object            a Math object

**Value**

An integer, the number of columns.

---

get.Math.nrows	<i>Method get.Math.nrows</i>
----------------	------------------------------

---

**Description**

It returns the number of rows of a Math object

**Usage**

```
## S4 method for signature 'Math'
get.Math.nrows(object)
```

**Arguments**

object            a Math object

**Value**

An integer, the number of rows.

---

get.Math.rownames	<i>Method get.Math.rownames</i>
-------------------	---------------------------------

---

**Description**

It returns the labels of the rows of a Math object

**Usage**

```
get.Math.rownames(object)

## S4 method for signature 'Math'
get.Math.rownames(object)
```

**Arguments**

object            a Math object

**Value**

A vector of char, the label of the rows.

---

get.Math.stats	<i>Method get.Math.stats</i>
----------------	------------------------------

---

**Description**

It returns statistics for each distribution contained in a Math object.

**Usage**

```
get.Math.stats(object, ...)
```

```
## S4 method for signature 'Math'
get.Math.stats(object, stat = "mean", prob = 0.5)
```

**Arguments**

object	a Math object
...	a set of other parameters
stat	(optional) a string containing the required statistic. Default='mean' - stat='mean' - for computing the mean of each histogram - stat='median' - for computing the median of each histogram - stat='min' - for computing the minimum of each histogram - stat='max' - for computing the maximum of each histogram - stat='std' - for computing the standard deviatio of each histogram - stat='skewness' - for computing the skewness of each histogram - stat='kurtosis' - for computing the kurtosis of each histogram - stat='quantile' - for computing the quantile ot level prob of each histogram
prob	(optional)a number between 0 and 1 for computing the value once choosen the 'quantile' option for stat.

**Value**

A list

**Slots**

stat - the chosen statistic  
prob - level of probability if stat='quantile'  
MAT - a matrix of values

**Examples**

```

get.Math.stats(BLOOD) # the means of the distributions in BLOOD dataset
get.Math.stats(BLOOD,stat='median') # the medians of the distributions in BLOOD dataset
get.Math.stats(BLOOD,stat='quantile', prob=0.5) #the same as median
get.Math.stats(BLOOD,stat='min') # minima of the distributions in BLOOD dataset
get.Math.stats(BLOOD,stat='quantile', prob=0) #the same as min
get.Math.stats(BLOOD,stat='max') # maxima of the distributions in BLOOD dataset
get.Math.stats(BLOOD,stat='quantile', prob=1) #the same as max
get.Math.stats(BLOOD,stat='std') # standard deviations of the distributions in BLOOD dataset
get.Math.stats(BLOOD,stat='skewness') #skewness indices of the distributions in BLOOD dataset
get.Math.stats(BLOOD,stat='kurtosis') #kurtosis indices of the distributions in BLOOD dataset
get.Math.stats(BLOOD,stat='quantile',prob=0.05)
#the fifth percentiles of distributions in BLOOD dataset

```

---

```

get.Math.varnames      Method get.Math.varnames

```

---

**Description**

It returns the labels of the columns, or the names of the variables, of a Math object

**Usage**

```

get.Math.varnames(object)

## S4 method for signature 'Math'
get.Math.varnames(object)

```

**Arguments**

object            a Math object

**Value**

A vector of char, the labels of the columns, or the names of the variables.

---

```

get.s                  Method get.s: the standard deviation of a distribution

```

---

**Description**

This function returns the standard deviation of a distributionH object.





---

HTS.exponential.smoothing

*Smoothing with exponential smoothing of a histogram time series*

---

### Description

(Beta version of) Extends the exponential smoothing of a time series to a histogram time series, using L2 Wasserstein distance.

### Usage

```
HTS.exponential.smoothing(HTS, alpha = 0.9)
```

### Arguments

HTS	A HTS object (a histogram time series).
alpha	a number between 0 and 1 for exponential smoothing

### Value

a list with the results of the smoothing procedure.

### Slots

smoothing.alpha	the alpha parameter
AveragedHTS	The smoothed HTS

### Examples

```
mov.expo.smooth=HTS.exponential.smoothing(HTS=RetHTS, alpha=0.8)
# a show method for HTS must be implemented you can see it using
# str(mov.expo.smooth$AveragedHTS)
```

---

HTS.moving.averages     *Smoothing with moving averages of a histogram time series*

---

### Description

(Beta version of) Extends the moving average smoothing of a time series to a histogram time series, using L2 Wasserstein distance.

### Usage

```
HTS.moving.averages(HTS, k = 3, weights = rep(1, k))
```

**Arguments**

HTS	A HTS object (a histogram time series).
k	an integer value, the number of elements for moving averages
weights	a vector of positive weights for a weighted moving average

**Value**

a list with the results of the smoothing procedure.

**Slots**

k	the number of elements for the average
weights	the vector of weights for smoothing
AveragedHTS	The smoothed HTS

**Examples**

```
mov.av.smoothed=HTS.moving.averages(HTS=RetHTS, k=5)
# a show method for HTS must be implemented you can see it using
# str(mov.av.smoothed$AveragedHTS)
```

---

HTS.predict.knn	<i>K-NN predictions of a histogram time series</i>
-----------------	--

---

**Description**

(Beta version of) Extends the K-NN algorithm for predicting a time series to a histogram time series, using L2 Wasserstein distance.

**Usage**

```
HTS.predict.knn(HTS, position = length(HTS@data), k = 3)
```

**Arguments**

HTS	A HTS object (a histogram time series).
position	an integer, the data histogram to predict
k	the number of neighbours (default=3)

**Details**

Histogram time series (HTS) describe situations where a distribution of values is available for each instant of time. These situations usually arise when contemporaneous or temporal aggregation is required. In these cases, histograms provide a summary of the data that is more informative than those provided by other aggregates such as the mean. Some fields where HTS are useful include economy, official statistics and environmental science. The function adapts the k-Nearest Neighbours (k-NN) algorithm to forecast HTS and, more generally, to deal with histogram data. The proposed k-NN relies on the L2 Wasserstein distance that is used to measure dissimilarities between sequences of histograms and to compute the forecasts.

**Value**

a `distributionH` object predicted from data.

**References**

Javier Arroyo, Carlos Mate, Forecasting histogram time series with k-nearest neighbours methods, *International Journal of Forecasting*, Volume 25, Issue 1, January-March 2009, Pages 192-207, ISSN 0169-2070, <http://dx.doi.org/10.1016/j.ijforecast.2008.07.003>.

**Examples**

```
prediction=HTS.predict.knn(HTS=RetHTS, position=108, k=3)
```

---

is.registeredMH	<i>Method is.registeredMH</i>
-----------------	-------------------------------

---

**Description**

Checks if a `Math` contains histograms described by the same number of bins and the same cdf.

**Usage**

```
is.registeredMH(object)

## S4 method for signature 'Math'
is.registeredMH(object)
```

**Arguments**

`object`            A `Math` object

**Value**

a logical value `TRUE` if the distributions share the same cdf, `FALSE` otherwise.

**Author(s)**

Antonio Irpino

**References**

Irpino, A., Lechevallier, Y. and Verde, R. (2006): *Dynamic clustering of histograms using Wasserstein metric* In: Rizzi, A., Vichi, M. (eds.) COMPSTAT 2006. Physica-Verlag, Berlin, 869-876.

Irpino, A., Verde, R. (2006): *A new Wasserstein based distance for the hierarchical clustering of histogram symbolic data* In: Batanjeli, V., Bock, H.H., Ferligoj, A., Ziberna, A. (eds.) Data Science and Classification, IFCS 2006. Springer, Berlin, 185-192.

**Examples**

```
##---- initialize three distributionH objects mydist1 and mydist2
mydist1=new("distributionH",c(1,2,3),c(0, 0.4, 1))
mydist2=new("distributionH",c(7,8,10,15),c(0, 0.2, 0.7, 1))
mydist3=new("distributionH",c(9,11,20),c(0, 0.8, 1))
## create a Math object
MyMAT=new("Math",nrows=1,ncols=3,ListOfDist=c(mydist1,mydist2,mydist3), 1,3)
is.registeredMH(MyMAT)
## [1] FALSE #the distributions do not share the same cdf
## Hint: check with str(MyMAT)

## register the two distributions
MATregistered=registerMH(MyMAT)
is.registeredMH(MATregistered)
## TRUE #the distributions share the same cdf
## Hint: check with str(MATregistered)
```

kurth

*Method kurth: computes the kurthosis of a distribution***Description**

Kurtosis of a histogram (using the fourth standardized moment)

**Usage**

```
kurth(object)

## S4 method for signature 'distributionH'
kurth(object)
```

**Arguments**

object            a distributionH object

**Value**

A value for the kurtosis index, 3 is the kurtosis of a Gaussian distribution

**Author(s)**

Antonio Irpino

**Examples**

```
##---- A mydist distribution ----
mydist<-distributionH(x=c(1,2,3,10), p=c(0,0.1,0.5,1))
##---- Compute the kurtosis of mydist ----
kurth(mydist) #----> 1.473242
```

---

Math-class

*Class Math.*

---

**Description**

Class Math defines a matrix of distributionH objects

This function create a matrix of histogram data, i.e. a Math object

**Usage**

```
## S4 method for signature 'Math'
initialize(.Object, nrows = 1, ncols = 1,
  ListOfDist = NULL, names.rows = NULL, names.cols = NULL,
  by.row = FALSE)

Math(x = NULL, nrows = 1, ncols = 1, rownames = NULL,
  varnames = NULL, by.row = FALSE)
```

**Arguments**

.Object	the object type "Math"
nrows	(optional, default=1)an integer, the number of rows.
ncols	(optional, default=1) an integer, the number of columns (aka variables).
ListOfDist	a vector or a list of distributionH objects
names.rows	a vector or list of strings with thenames of the rows
names.cols	a vector or list of strings with thenames of the columns (variables)
by.row	(optional, default=FALSE) a logical value, TRUE the matrix is row wise filled, FALSE the matrix is filled column wise.

x	(optional, default= an empty distributionH object) a list of distributionH objects
rownames	(optional, default=NULL) a list of strings containing the names of the rows.
varnames	(optional, default=NULL) a list of strings containing the names of the columns (aka variables).

**Value**

A math object

**Author(s)**

Antonio Irpino

**References**

Irpino, A., Verde, R. (2015) *Basic statistics for distributional symbolic variables: a new metric-based approach* Advances in Data Analysis and Classification, DOI 10.1007/s11634-014-0176-4

**Examples**

```
##---- create a list of six distributionH objects
ListOfDist<-vector("list",6)
ListOfDist[[1]]<-distributionH(c(1,2,3),c(0, 0.4, 1))
ListOfDist[[2]]<-distributionH(c(7,8,10,15),c(0, 0.2, 0.7, 1))
ListOfDist[[3]]<-distributionH(c(9,11,20),c(0, 0.5, 1))
ListOfDist[[4]]<-distributionH(c(2,5,8),c(0, 0.3, 1))
ListOfDist[[5]]<-distributionH(c(8,10,15),c(0, 0.75, 1))
ListOfDist[[6]]<-distributionH(c(20,22,24),c(0, 0.12, 1))

## create a Math object filling it by columns
MyMAT=new("Math",nrows=3,ncols=2,ListOfDist=ListOfDist,
  names.rows=c("I1","I2","I3"), names.cols=c("Var1","Var2"),by.row=FALSE)

showClass("Math")

#bulding an empty 10 by 4 matrix of histograms
MAT=Math(nrows=10,ncols=4)
```

---

meanH

*Method meanH: computes the mean of a distribution*

---

**Description**

Mean of a histogram (First moment of the distribution)

**Usage**

```
meanH(object)

## S4 method for signature 'distributionH'
meanH(object)
```

**Arguments**

object            a distributionH object

**Value**

the mean of the distribution

**Author(s)**

Antonio Irpino

**Examples**

```
##---- A mydist distribution ----
mydist<-distributionH(x=c(1,2,3,10), p=c(0,0.1,0.5,1))
##---- Compute the mean of mydist ----
meanH(mydist) #--> 4.4
```

---

minus

*Method -*

---

**Description**

the difference of two distribution according to the L2 Wasssertein

the difference of a number and a distribution according to the L2 Wasssertein

the difference of a distribution and a number according to the L2 Wasssertein

**Usage**

```
## S4 method for signature 'distributionH,distributionH'
e1 - e2

## S4 method for signature 'numeric,distributionH'
e1 - e2

## S4 method for signature 'distributionH,numeric'
e1 - e2
```



**Arguments**

e1                    a distributionH object or a number  
 e2                    a distributionH object or a number

**Note**

it may not works properly if the difference is not a distribution

---

OzoneFull	<i>Full Ozone dataset for Histogram data analysis</i>
-----------	---

---

**Description**

The dataset contains MatH (matrix of histogram-valued data) object This data set list 78 stations located in the USA recording four variables, without missing data.

**Format**

a MatH instance, 1 row per station.

**Author(s)**

Antonio Irpino, 2014-10-05

**Source**

[http://java.epa.gov/castnet/epa\\_jsp/prepackageddata.jsp](http://java.epa.gov/castnet/epa_jsp/prepackageddata.jsp) <ftp://ftp.epa.gov/castnet/data/metdata.zip>

---

OzoneH	<i>Complete Ozone dataset for Histogram data analysis</i>
--------	---

---

**Description**

The dataset contains MatH (matrix of histogram-valued data) object This data set list 84 stations located in the USA recording four variables. Some stations contains missing data.

**Format**

a MatH instance, 1 row per station.

**Author(s)**

Antonio Irpino, 2014-10-05

**Source**

[http://java.epa.gov/castnet/epa\\_jsp/prepackageddata.jsp](http://java.epa.gov/castnet/epa_jsp/prepackageddata.jsp) <ftp://ftp.epa.gov/castnet/data/metdata.zip>

---

plot-distributionH     *plot for a distributionH object*

---

### Description

A plot function for a distributionH object. The function returns a representation of the histogram.

### Usage

```
## S4 method for signature 'distributionH'
plot(x, type = "HISTO", col = "green",
     border = "black")
```

### Arguments

x	a distributionH object
type	(optional) a string describing the type of plot, default="HISTO". Other allowed types are "CDF"=Cumulative distribution function, "QF"= quantile function, "DENS"=a density approximation, "HBOXPLOT"=horizontal boxplot, "VBOXPLOT"= vertical boxplot,
col	(optional) a string the color of the plot, default="green".
border	(optional) a string the color of the border of the plot, default="black".
...	other optional parameters

### Examples

```
##---- initialize a distributionH
mydist<-distributionH(x=c(7,8,10,15),p=c(0, 0.2, 0.7, 1))
# show the histogram
plot(mydist) #plots mydist
plot(mydist, type="HISTO", col="red", border="blue") #plots mydist
plot(mydist, type="DENS", col="red", border="blue") #plots a density approximation for mydist
plot(mydist, type="HBOXPLOT") #plots a horizontal boxplot for mydist
plot(mydist, type="VBOXPLOT") #plots a vertical boxplot for mydist
plot(mydist, type="CDF") #plots the cumulative distribution function of mydist
plot(mydist, type="QF") #plots the quantile function of mydist
```

---

plot-HTS

*Method plot for a histogram time series*


---

**Description**

An overloading plot function for a HTS object. The method returns a graphical representation of a histogram time series.

**Usage**

```
## S4 method for signature 'HTS'
plot(x, y = "missing", type = "VIOLIN",
     border = "black", maxno.perplot = 30)
```

**Arguments**

x	a distributionH object
y	not used in this implementation
type	(optional) a string describing the type of plot, default="BOXPLOT". Other allowed types are "VIOLIN"=a violin-plot representation,
border	(optional) a string the color of the border of the plot, default="black".
maxno.perplot	An integer (DEFAULT=30). Maximum number of timestamps per row. It allows a plot organized by rows, each row of the plot contains a max number of time stamps indicated by maxno.perplot.

**Examples**

```
plot(subsetHTS(RetHTS,from=1,to=10)) #plots RetHTS dataset
## Not run:
plot(RetHTS, type="BOXPLOT", border="blue", maxno.perplot=20)
plot(RetHTS, type="VIOLIN", border="blue", maxno.perplot=20)
plot(RetHTS, type="VIOLIN", border="blue", maxno.perplot=10)

## End(Not run)
```

---

plot-MatH

*Method plot for a matrix of histograms*


---

**Description**

An overloading plot function for a MatH object. The method returns a graphical representation of the matrix of histograms.

**Usage**

```
## S4 method for signature 'Math'
plot(x, y = "missing", type = "HISTO",
     border = "black", angl = 330)
```

**Arguments**

x	a distributionH object
y	not used in this implementation
type	(optional) a string describing the type of plot, default="HISTO". Other allowed types are "DENS"=a density approximation, "BOXPLOT"=l boxplot
border	(optional) a string the color of the border of the plot, default="black".
angL	(optional) angle of labels of rows (DEFAULT=330).

**Examples**

```
plot(BLOOD) #plots BLOOD dataset
## Not run:
plot(BLOOD, type="HISTO", border="blue") #plots a matrix of histograms
plot(BLOOD, type="DENS", border="blue") #plots a matrix of densities
plot(BLOOD, type="BOXPLOT") #plots a boxplots

## End(Not run)
```

---

plot-TdistributionH    *plot for a TdistributionH object*

---

**Description**

A plot function for a TdistributionH object. The function returns a representation of the histogram.

**Usage**

```
## S4 method for signature 'TdistributionH'
plot(x, type = "HISTO", col = "green",
     border = "black")
```

**Arguments**

x	a TdistributionH object
---	-------------------------

type	(optional) a string describing the type of plot, default="HISTO". Other allowed types are "CDF"=Cumulative distribution function, "QF"= quantile function, "DENS"=a density approximation, "HBOXPLOT"=horizontal boxplot, "VBOXPLOT"= vertical boxplot,
col	(optional) a string the color of the plot, default="green".
border	(optional) a string the color of the border of the plot, default="black".

---

plotPredVsObs	<i>A function for comparing observed vs predicted histograms</i>
---------------	--

---

### Description

This function allows the representation of observed vs predicted histograms. It can be used as a tool for interpreting predictive methods (for example, the regression of histogram data)

### Usage

```
plotPredVsObs(PRED, OBS, type = "HISTO", ncolu = 2)
```

### Arguments

PRED	a Math object with one column, the predicted data
OBS	a Math object with one column, the observed data
type	a string. "HISTO" (default), if ones want to compare histograms "CDF", if ones want to compare cumulative distribution functions; "DENS" if ones want to compare approximated densities (using KDE);
ncolu	number of columns in which is arranged the plot, default is 2. If you have a lot of data consider to choose higher values.

### Value

A plot with compared histogram-valued data.

### Examples

```
## do a regression
pars=WH.regression.two.components(BLOOD,Yvar = 1,Xvars = c(2:3))
## predict data
PRED=WH.regression.two.components.predict(data = BLOOD[,2:3],parameters = pars)
## define observed data
## Not run:
OBS=BLOOD[,1]
plotPredVsObs(PRED,OBS,"HISTO")
```

```
plotPredVsObs(PRED,OBS,"CDF")
plotPredVsObs(PRED,OBS,"DENS")

## End(Not run)
```

---

plot\_errors                      *A function for plotting functions of errors*

---

## Description

This function allows the representation of the difference between observed histograms and the respective predicted ones. It can be used as a tool for interpreting predictive methods (for example, the regression of histogram data)

## Usage

```
plot_errors(PRED, OBS, type = "HISTO_QUA", np = 200)
```

## Arguments

PRED	a Math object with one column, the predicted data
OBS	a Math object with one column, the observed data
type	a string. "HISTO_QUA" (default), if ones want to compare histograms quantile differences "HISTO_DEN", if ones want to show the histogram densities differences; "DENS_KDE" if ones want to show the differences between approximated densities (using KDE);
np	number of points considered for density or quantile computation (default=200).

## Value

A plot with functions of differences between observed and predicted histograms, and a Root Mean Squared value computing by using the L2 Wasserstein distance.

## Examples

```
## do a regression
pars=WH.regression.two.components(BLOOD,Yvar = 1,Xvars = c(2:3))
## predict data
PRED=WH.regression.two.components.predict(data = BLOOD[,2:3],parameters = pars)
## define observed data
OBS=BLOOD[,1]
plot_errors(PRED,OBS,"HISTO_QUA")
plot_errors(PRED,OBS,"HISTO_DEN")
plot_errors(PRED,OBS,"DENS_KDE")
```

---

register	<i>Method register</i>
----------	------------------------

---

**Description**

Given two `distributionH` objects, it returns two equivalent distributions such that they share the same cdf values. This function is useful for computing basic statistics.

**Usage**

```
register(object1, object2)

## S4 method for signature 'distributionH,distributionH'
register(object1, object2)
```

**Arguments**

object1	A <code>distributionH</code> object
object2	A <code>distributionH</code> object

**Value**

The two `distributionH` objects in input sharing the same cdf (the p slot)

**Author(s)**

Antonio Irpino

**References**

Irpino, A., Lechevallier, Y. and Verde, R. (2006): *Dynamic clustering of histograms using Wasserstein metric* In: Rizzi, A., Vichi, M. (eds.) COMPSTAT 2006. Physica-Verlag, Berlin, 869-876.  
 Irpino, A., Verde, R. (2006): *A new Wasserstein based distance for the hierarchical clustering of histogram symbolic data* In: Batanjeli, V., Bock, H.H., Ferligoj, A., Ziberna, A. (eds.) Data Science and Classification, IFCS 2006. Springer, Berlin, 185-192.

**Examples**

```
##---- initialize two distributionH objects mydist1 and mydist2
mydist1=distributionH(c(1,2,3),c(0, 0.4, 1))
mydist2=distributionH(c(7,8,10,15),c(0, 0.2, 0.7, 1))
## register the two distributions
regDist=register(mydist1,mydist2)

## OUTPUT:
## regDist$[[1]]
## An object of class "distributionH"
```

```
## Slot "x": [1] 1.0 1.5 2.0 2.5 3.0
## Slot "p": [1] 0.0 0.2 0.4 0.7 1.0
## ...
## regDist$[[2]]
## An object of class "distributionH"
## Slot "x": [1] 7.0 8.0 8.8 10.0 15.0
## Slot "p": [1] 0.0 0.2 0.4 0.7 1.0
## ...
```

---

registerMH

*Method registerMH*


---

### Description

registerMH method registers a set of distributions of a Math object All the distribution are re-computed to obtain distributions sharing the same p slot. This methods is useful for using fast computation of all methods based on L2 Wasserstein metric. The distributions will have the same number of element in the x slot without modifying their density function.

### Usage

```
registerMH(object)

## S4 method for signature 'Math'
registerMH(object)
```

### Arguments

object            A Math object (a matrix of distributions)

### Value

A Math object, a matrix of distributions sharing the same p slot (i.e. the same cdf).

### Author(s)

Antonio Irpino

### References

Irpino, A., Lechevallier, Y. and Verde, R. (2006): *Dynamic clustering of histograms using Wasserstein metric* In: Rizzi, A., Vichi, M. (eds.) COMPSTAT 2006. Physica-Verlag, Berlin, 869-876.  
Irpino, A., Verde, R. (2006): *A new Wasserstein based distance for the hierarchical clustering of histogram symbolic data* In: Batanjeli, V., Bock, H.H., Ferligoj, A., Ziberna, A. (eds.) Data Science and Classification, IFCS 2006. Springer, Berlin, 185-192.



**Examples**

```

#initialize three distributionH objects mydist1 and mydist2
mydist1=new("distributionH",c(1,2,3),c(0, 0.4, 1))
mydist2=new("distributionH",c(7,8,10,15),c(0, 0.2, 0.7, 1))
mydist3=new("distributionH",c(9,11,20),c(0, 0.8, 1))
# create a Math object

MyMAT=new("Math",nrows=1,ncols=3,ListOfDist=c(mydist1,mydist2,mydist3), 1,3)
# register the two distributions
MATregistered=registerMH(MyMAT)
# OUTPUT the structure of MATregistered
str(MATregistered)
#  Formal class 'Math' [package "HistDAWass"] with 1 slots
#  .. @ M:List of 3
#  .. ..$ :Formal class 'distributionH' [package "HistDAWass"] with 4 slots
#  .. .. . .@ x: num [1:6] 1 1.5 2 2.5 2.67 ...
#  .. .. . .@ p: num [1:6] 0 0.2 0.4 0.7 0.8 1
#  ...
#  .. ..$ :Formal class 'distributionH' [package "HistDAWass"] with 4 slots
#  .. .. . .@ x: num [1:6] 7 8 8.8 10 11.7 ...
#  .. .. . .@ p: num [1:6] 0 0.2 0.4 0.7 0.8 1
#  ...
#  .. ..$ :Formal class 'distributionH' [package "HistDAWass"] with 4 slots
#  .. .. . .@ x: num [1:6] 9 9.5 10 10.8 11 ...
#  .. .. . .@ p: num [1:6] 0 0.2 0.4 0.7 0.8 1
#  ...
#  .. ..- attr(*, "dim")= int [1:2] 1 3
#  .. ..- attr(*, "dimnames")=List of 2
#  .. .. ..$ : chr "I1"
#  .. .. ..$ : chr [1:3] "X1" "X2" "X3"

```

RetHTS

*A histogram-valued dataset of returns***Description**

A histogram-valued dataset of returns of dollar vs yen change rates

**Format**

a Math object, a matrix of distributions.

**Author(s)**

Antonio Irpino, 2014-10-05

---

rQQ

*Method* rQQ

---

### Description

Quantile-Quantile correlation between two distributions

### Usage

```
rQQ(e1, e2)
```

```
## S4 method for signature 'distributionH,distributionH'  
rQQ(e1, e2)
```

### Arguments

e1            A distributionH object

e2            A distributionH object

### Value

Pearson correlation index between quantiles

### Author(s)

Antonio Irpino

### References

Irpino, A., Verde, R. (2015) *Basic statistics for distributional symbolic variables: a new metric-based approach* Advances in Data Analysis and Classification, DOI 10.1007/s11634-014-0176-4

### Examples

```
##---- initialize two distributionH object mydist1 and mydist2  
mydist1<-distributionH(x=c(1,2,3),p=c(0, 0.4, 1))  
mydist2<-distributionH(x=c(7,8,10,15),p=c(0, 0.2, 0.7, 1))  
## computes the rQQ  
rQQ(mydist1,mydist2)  
## OUTPUT 0.916894
```

---

set.cell.Math	<i>Method set.cell.Math assign a histogram to a cell of a matrix of histograms</i>
---------------	--

---

**Description**

Assign a histogram data to the r-th row and the c-th column of a matrix of histograms.

**Usage**

```
set.cell.Math(object, mat, r, c)
```

```
## S4 method for signature 'distributionH,Math,numeric,numeric'
set.cell.Math(object, mat,
  r, c)
```

**Arguments**

object	a distributionH object, a matrix of distributions.
mat	a MatH object, a matrix of distributions.
r	an integer, the row index.
c	an integer, the column index

**Value**

A Math object.

**Examples**

```
mydist=distributionH(x=c(0,1,2,3,4), p=c(0,0.1,0.6,0.9,1))
MAT=set.cell.Math(mydist,BLOOD, r=1,c=1)
```

---

ShortestDistance	<i>Shortes distance from a point o a 2d segment</i>
------------------	---

---

**Description**

Shortes distance from a point o a 2d segment

**Usage**

```
ShortestDistance(p, line)
```

**Arguments**

p coordinates of a point  
line a 2x2 matrix with the coordinates of two points defining a line

**Value**

A numeric value, the Euclidean distance of point p to the line.

**See Also**

[data2hist](#) function and [DouglasPeucker](#) function

---

show	<i>Method show for distributionH</i>
------	--------------------------------------

---

**Description**

An overriding show function for a `distributionH` object. The function returns a representation of the histogram, if the number of bins is high the central part of the histogram is truncated.

**Usage**

```
## S4 method for signature 'distributionH'  
show(object)
```

**Arguments**

object a `distributionH` object

**Examples**

```
##---- initialize a distributionH  
mydist<-distributionH(x=c(7,8,10,15),p=c(0, 0.2, 0.7, 1))  
# show the histogram  
mydist
```

---

show-MatH	<i>Method show for MatH</i>
-----------	-----------------------------

---

**Description**

An overriding show method for a MatH object. The method returns a representation of the matrix using the mean and the standard deviation for each histogram.

**Usage**

```
## S4 method for signature 'MatH'  
show(object)
```

**Arguments**

object            a MatH object

**Examples**

```
show(BLOOD)  
print(BLOOD)  
BLOOD
```

---

skewH	<i>Method skewH: computes the skewness of a distribution</i>
-------	--

---

**Description**

Skewness of a histogram (using the third standardized moment)

**Usage**

```
skewH(object)  
  
## S4 method for signature 'distributionH'  
skewH(object)
```

**Arguments**

object            a distributionH object

**Value**

A value for the skewness index

**Author(s)**

Antonio Irpino

**Examples**

```
##---- A mydist distribution ----
mydist<-distributionH(x=c(1,2,3,10), p=c(0,0.1,0.5,1))
##---- Compute the skewness of mydist ----
skewH(mydist) #--> -1.186017
```

---

stations\_coordinates    *Stations coordinates of China\_Month and China\_Seas datasets*

---

**Description**

A dataset containing the geographical coordinates of stations described in China\_Month and China\_Seas datasets

**Format**

a data.frame

**Author(s)**

Antonio Irpino, 2014-10-05

**Source**

raw data are available here: <http://cdiac.ess-dive.lbl.gov/ftp/tr055/>. Climate Data Bases of the People's Republic of China 1841-1988 (TR055) DOI: 10.3334/CDIAC/cli.tr055

---

stdH                            *Method stdH: computes the standard deviation of a distribution*

---

**Description**

Standard deviation of a histogram (i.e., the square root of the centered second moment)

**Usage**

```
stdH(object)

## S4 method for signature 'distributionH'
stdH(object)
```

**Arguments**

object            a distributionH object

**Value**

A value for the standard deviation

**Author(s)**

Antonio Irpino

**Examples**

```
##---- A mydist distribution ----
mydist<-distributionH(x=c(1,2,3,10), p=c(0,0.1,0.5,1))
##---- Compute the standard deviation of mydist ----
stdH(mydist) #--> 2.563851
```

---

subsetHTS

*Method subsetHTS: extract a subset of a histogram time series*


---

**Description**

This function return the mean of a distributionH object.

**Usage**

```
subsetHTS(object, from, to)
```

```
## S4 method for signature 'HTS,numeric,numeric'
subsetHTS(object, from, to)
```

**Arguments**

object            a HTS object. A histogram 1d time series  
from              an integer, the initial timepoint  
to                an integer, a final timepoint

**Value**

a HTS object. A histogram 1d time series

**Examples**

```
SUB_RetHTS=subsetHTS(RetHTS,from=1, to=20)# the first 20 elements
```

---

TdistributionH-class    *Class TdistributionH*

---

### Description

Class TdistributionH defines a histogram with a time (point or period)

### Usage

```
## S4 method for signature 'TdistributionH'
initialize(.Object, tstamp = numeric(0),
  period = list(start = -Inf, end = -Inf), x = numeric(0),
  p = numeric(0), m = numeric(0), s = numeric(0))
```

### Arguments

.Object	the type of object ("TdistributionH") a "distributionH" object with a time reference
tstamp	a numeric value related to a timestamp
period	a list of two values, the starting time and the ending time (alternative to tstamp if the distribution is observed along a period and not on a timestamp)
x	a vector of increasing values, the domain of the distribution (the same of distributionH object)
p	a vector of increasing values from 0 to 1, the CDF of the distribution (the same of distributionH object)
m	a number, the mean of the distribution (the same of distributionH object)
s	a positive number, the standard deviation of the distribution (the same of distributionH object)

---

TMath-class    *Class TMath*

---

### Description

Class TMath defines a matrix of histograms, a TMath object, with a time (a timepoint or a time window).

### Usage

```
## S4 method for signature 'TMath'
initialize(.Object, tstamp = numeric(0),
  period = list(start = -Inf, end = -Inf), mat = new("Math"))
```



**Arguments**

.Object	the type of object ("TMath")
tstamp	a vector of time stamps, numeric.
period	a list of pairs with a vector of starting time and a vector of ending time. This parameter is used alternatively to tstamp if the distributions are related to time periods instead of timestamps
mat	a Math object

---

WassSqDistH

*Method* WassSqDistH

---

**Description**

Computes the squared L2 Wasserstein distance between two distributionH objects.

**Usage**

```
WassSqDistH(object1, object2, ...)
```

```
## S4 method for signature 'distributionH,distributionH'
WassSqDistH(object1 = object1,
  object2 = object2, details = FALSE)
```

**Arguments**

object1	is an object of distributionH class
object2	is an object of distributionH class
...	optional parameters
details	(optional, default=FALSE) is a logical value, if TRUE returns the decomposition of the distance

**Value**

If details=FALSE, the function returns the squared L2 Wasserstein distance.

If details=TRUE, the function returns list containing the squared distance, its decomposition in three parts (position, size and shape) and the correlation coefficient between the quantile functions.

**References**

Irpino, A. and Romano, E. (2007): *Optimal histogram representation of large data sets: Fisher vs piecewise linear approximations*. RNTI E-9, 99-110.

Irpino, A., Verde, R. (2015) *Basic statistics for distributional symbolic variables: a new metric-based approach* Advances in Data Analysis and Classification, DOI 10.1007/s11634-014-0176-4

## Examples

```
##---- create two distributionH objects ----
mydist1=distributionH(x=c(1,2,3),p=c(0, 0.4, 1))
mydist2=distributionH(x=c(7,8,10,15),p=c(0, 0.2, 0.7, 1))
# -- compute the squared L2 Waaserstein distance
WassSqDistH(mydist1,mydist2)
# -- compute the squared L2 Waaserstein distance with details
WassSqDistH(mydist1,mydist2,details=TRUE)
```

---

WH.1d.PCA

*Principal components analysis of histogram variable based on Wasserstein distance*

---

## Description

The function implements a Principal components analysis of histogram variable based on Wasserstein distance. It performs a centered (not standardized) PCA on a set of quantiles of a variable. Being a distribution a multivalued description, the analysis performs a dimensional reduction and a visualization of distributions. It is a 1d (one dimension) because it is considered just one histogram variable.

## Usage

```
WH.1d.PCA(data, var, quantiles = 10, plots = TRUE, listaxes = c(1:4),
  axisequal = FALSE, qcut = 1, outl = 0)
```

## Arguments

<code>data</code>	A MatH object (a matrix of distributionH).
<code>var</code>	An integer, the variable number.
<code>quantiles</code>	An integer, it is the number of quantiles used in the analysis.
<code>plots</code>	a logical value. Default=TRUE plots are drawn.
<code>listaxes</code>	A vector of integers listing the axis for the 2d factorial representations.
<code>axisequal</code>	A logical value. Default TRUE, the plot have the same scale for the x and the y axes.
<code>qcut</code>	a number between 0.5 and 1, it is used for the plot of densities, and avoids very peaked densities. Default=1, all the densities are considered.
<code>outl</code>	a number between 0 (default) and 0.5. For each distribution, is the amount of mass removed from the tails of the distribution. For example, if 0.1, from each distribution is cut away a left tail and a right one each containing the 0.1 of mass.

## Details

In the framework of symbolic data analysis (SDA), distribution-valued data are defined as multivalued data, where each unit is described by a distribution (e.g., a histogram, a density, or a quantile function) of a quantitative variable. SDA provides different methods for analyzing multivalued data. Among them, the most relevant techniques proposed for a dimensional reduction of multivalued quantitative variables is principal component analysis (PCA). This paper gives a contribution in this context of analysis. Starting from new association measures for distributional variables based on a peculiar metric for distributions, the squared Wasserstein distance, a PCA approach is proposed for distribution-valued data, represented by quantile-variables.

## Value

a list with the results of the PCA in the MFA format of package **FactoMineR** for function MFA

## References

Verde, R.; Iripino, A.; Balzanella, A., "Dimension Reduction Techniques for Distributional Symbolic Data," Cybernetics, IEEE Transactions on , vol.PP, no.99, pp.1,1 doi: 10.1109/TCYB.2015.2389653  
 keywords: Correlation;Covariance matrices;Distribution functions;Histograms;Measurement;Principal component analysis;Shape;Distributional data;Wasserstein distance;principal components analysis;quantiles, <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7024099&isnumber=6352949>

## Examples

```
results=WH.1d.PCA(data = BLOOD,var = 1, listaxes=c(1:2))
```

---

WH.bind

*Method WH.bind*

---

## Description

It attaches two Math objects with the same columns by row, or the same rows by column.

## Usage

```
WH.bind(object1, object2, byrow)

## S4 method for signature 'Math,Math'
WH.bind(object1, object2, byrow = TRUE)
```

## Arguments

object1	a Math object
object2	a Math object
byrow	a logical value (default=TRUE) attaches the objects by row

**Value**

a MatH object,

**See Also**

[WH.bind.row](#) for binding by row, [WH.bind.col](#) for binding by column

**Examples**

```
# binding by row
M1<-BLOOD[1:10,1]
M2<-BLOOD[1:10,3]
MAT<-WH.bind(M1,M2, byrow=TRUE)
# binding by col
M1<-BLOOD[1:10,1]
M2<-BLOOD[1:10,3]
MAT<-WH.bind(M1,M2, byrow=FALSE)
```

---

WH.bind.col

*Method WH.bind.col*

---

**Description**

It attaches two MatH objects with the same rows by columns.

**Usage**

```
WH.bind.col(object1, object2)
```

```
## S4 method for signature 'Math,Math'
WH.bind.col(object1, object2)
```

**Arguments**

```
object1      a MatH object
object2      a MatH object
```

**Value**

a MatH object,

**Examples**

```
M1<-BLOOD[1:10,1]
M2<-BLOOD[1:10,3]
MAT<-WH.bind.col(M1,M2)
```

---

WH.bind.row	<i>Method WH.bind.row</i>
-------------	---------------------------

---

**Description**

It attaches two Math objects with the same columns by row.

**Usage**

```
WH.bind.row(object1, object2)
```

```
## S4 method for signature 'Math,Math'
```

```
WH.bind.row(object1, object2)
```

**Arguments**

object1            a Math object

object2            a Math object

**Value**

a Math object,

**Examples**

```
M1<-BLOOD[1:3,]
M2<-BLOOD[5:8,]
MAT<-WH.bind.row(M1,M2)
```

---

WH.correlation	<i>Method WH.correlation</i>
----------------	------------------------------

---

**Description**

Compute the correlation matrix of a Math object, i.e. a matrix of values consistent with a set of distributions equipped with a L2 wasserstein metric.

**Usage**

```
WH.correlation(object, ...)
```

```
## S4 method for signature 'Math'
```

```
WH.correlation(object, w = numeric(0))
```

**Arguments**

object	a Math object
...	some optional parameters
w	it is possible to add a vector of weights (positive numbers) having the same size of the rows of the Math object, default = equal weight for each row

**Value**

a squared matrix with the (weighted) correlations indices

**References**

Irpino, A., Verde, R. (2015) *Basic statistics for distributional symbolic variables: a new metric-based approach* Advances in Data Analysis and Classification, DOI 10.1007/s11634-014-0176-4

**Examples**

```
WH.correlation(BLOOD)
# generate a set of random weights
RN<-runif(get.Math.nrows(BLOOD))
WH.correlation(BLOOD,w=RN)
```

---

WH.correlation2      *Method WH.correlation2*

---

**Description**

Compute the correlation matrix using two Math objects having the same number of rows, It returns a rectangular a matrix of numbers, consistent with a set of distributions equipped with a L2 wasserstein metric.

**Usage**

```
WH.correlation2(object1, object2, ...)

## S4 method for signature 'Math,Math'
WH.correlation2(object1, object2, w = numeric(0))
```

**Arguments**

object1	a Math object
object2	a Math object
...	some optional parameters
w	it is possible to add a vector of weights (positive numbers) having the same size of the rows of the Math object, default = equal weight for each row

**Value**

a rectangular matrix with the weighted sum of squares

**Examples**

```
M1<-BLOOD[,1]
M2<-BLOOD[,2:3]
WH.correlation2(M1,M2)
# generate a set of random weights
RN<-runif(get.Math.nrows(BLOOD))
WH.correlation2(M1,M2,w=RN)
```

---

 WH.mat.prod

*Method WH.mat.prod*


---

**Description**

It is the matrix product of two Math objects, i.e. two matrices of distributions, by using the dot product of two histograms that is consistent with a set of distributions equipped with a L2 wasserstein metric.

**Usage**

```
WH.mat.prod(object1, object2, ...)

## S4 method for signature 'Math,Math'
WH.mat.prod(object1, object2, traspose1 = FALSE,
  traspose2 = FALSE)
```

**Arguments**

object1	a Math object
object2	a Math object
...	other optional parameters
traspose1	a logical value, default=FALSE. If TRUE trasposes object1
traspose2	a logical value, default=FALSE. If TRUE trasposes object2

**Value**

a matrix of numbers

**Examples**

```
M1<-BLOOD[1:5,]
M2<-BLOOD[6:10,]
MAT<-WH.mat.prod(M1,M2,traspose1=TRUE, traspose2=FALSE)
```

---

WH.mat.sum	<i>Method WH.mat.sum</i>
------------	--------------------------

---

**Description**

It sums two MatH objects, i.e. two matrices of distributions, by summing the quantile functions of histograms. This sum is consistent with a set of distributions equipped with a L2 wasserstein metric.

**Usage**

```
WH.mat.sum(object1, object2)

## S4 method for signature 'MatH,MatH'
WH.mat.sum(object1, object2)
```

**Arguments**

object1	a MatH object
object2	a MatH object

**Value**

a MatH object,

**Examples**

```
# binding by row
M1<-BLOOD[1:5,]
M2<-BLOOD[6:10,]
MAT<-WH.mat.sum(M1,M2)
```

---

WH.MultiplePCA	<i>Principal components analysis of a set of histogram variable based on Wasserstein distance</i>
----------------	---

---

**Description**

(Beta version) The function implements a Principal components analysis of a set of histogram variables based on Wasserstein distance. It performs a centered (not standardized) PCA on a set of quantiles of a variable. Being a distribution a multivalued description, the analysis performs a dimensional reduction and a visualization of distributions. It is a 1d (one dimension) because it is considered just one histogram variable.

**Usage**

```
WH.MultiplePCA(data, list.of.vars, quantiles = 10, outl = 0)
```



**Arguments**

data	A MatH object (a matrix of distributionH).
list.of.vars	A list of integers, the active variables.
quantiles	An integer, it is the number of quantiles used in the analysis. Default=10.
out1	a number between 0 (default) and 0.5. For each distribution, is the amount of mass removed from the tails of the distribution. For example, if 0.1, from each distribution is cut away a left tail and a right one each containing the 0.1 of mass.

**Details**

It is an extension of WH.1d.PCA to the multiple case.

**Value**

a list with the results of the PCA in the MFA format of package **FactoMineR** for function MFA

---

WH.plot\_multiple\_indivs

*Plot histograms of individuals after a Multiple factor analysis of Histogram Variables*

---

**Description**

(Beta version) The function plots histogram data of the individuals for a particular variable on a factorial plane after a Multiple factor analysis.

**Usage**

```
WH.plot_multiple_indivs(data, res, axes = c(1, 2), indiv = 0,
  var = 1, strx = 0.1, stry = 0.1, HISTO = TRUE, coor = 0,
  stat = "mean")
```

**Arguments**

data	a MatH object
res	Results from WH.MultiplePCA.
axes	A list of integers, the new factorial axes c(1,2) are the default.
indiv	A list of objects (rows) of data to plot. Default=0 all the objects of data.
var	An integer indicating an original histogram variable to plot.
strx	a resizing factor for the domain of histograms (default=0.1 means that each distribution has a support that is one tenth of the spread of the x axis)
stry	a resizing factor for the density of histograms (default=0.1 means that each distribution has a density that is one tenth of the spread of the y axis)
HISTO	a logical value. Default=TRUE plots histograms, FALSE plot smooth densities.

coor	(optional) if 0 (Default) takes the coordinates in res, if a a matrix is passed the coordinates are those passed
stat	(optional) if 'mean'(Default) a plot of individuals labeled by the means is produced. Otherwise if 'std', 'skewness' or 'kurtosis', data are labeled with this statistic.

**Value**

a plot of class ggplot

**Examples**

```
#Do a MultiplePCA on the BLOOD dataset
## Not run:
#' results=WH.MultiplePCA(BLOOD,list.of.vars = c(1:3))
#Plot histograms of variable 1 of BLOOD dataset on the first
#factorial plane showing histograms
WH.plot_multiple_indivs(BLOOD,results,axes=c(1,2),var=1,strx=0.1,
  stry=0.1, HISTO=TRUE)
#Plot histograms of variable 1 of BLOOD dataset on the first
#factorial plane showing densities
WH.plot_multiple_indivs(BLOOD,results,axes=c(1,2),var=1,strx=0.1,
  stry=0.1, HISTO=FALSE)

## End(Not run)
```

---

WH.plot\_multiple\_Spanish.funs

*Plotting Spanish fun plots for Multiple factor analysis of Histogram Variables*

---

**Description**

The function plots the circle of correlation of the quantiles of the histogram variables after a Multiple factor analysis.

**Usage**

```
WH.plot_multiple_Spanish.funs(res, axes = c(1, 2), var = 1,
  LABS = TRUE, multi = TRUE, corplot = TRUE)
```

**Arguments**

res	Results from WH.MultiplePCA, or WH.ID.PCA.
axes	A list of integers, the new factorial axes c(1,2) are the default.
var	A list of integers are the variables to plot.
LABS	Logical, if TRUE graph is labeled, otherwise it does not.

multi	Logical, if TRUE (default) results come from a WH.MultiplePCA, if FALSE results come from WH.1D.PCA.
corplot	Logical, if TRUE (default) the plot reports correlations, if FALSE the coordinates of quantiles on the factorial plane

**Value**

a plot of class ggplot

**Examples**

```
#Do a MultiplePCA on the BLOOD dataset
## Not run:
res=WH.MultiplePCA(BLOOD,list.of.vars = c(1:3))

## End(Not run)
#Plot results
## Not run:
WH.plot_multiple_Spanish.funs(res,axes=c(1,2),var=c(1:3))

## End(Not run)
```

---

WH.regression.GOF	<i>Goodness of Fit indices for Multiple regression of histogram variables based on a two component model and L2 Wasserstein distance</i>
-------------------	--

---

**Description**

It computes three goodness of fit indices using the results and the predictions of a regression done with WH.regression.two.components function.

**Usage**

```
WH.regression.GOF(observed, predicted)
```

**Arguments**

observed	A one column MatH object, the observed histogram variable
predicted	A one column MatH object, the predicted histogram variable.

**Value**

a list with the GOF indices

## References

Irpino A, Verde R (in press 2015). Linear regression for numeric symbolic variables: a least squares approach based on Wasserstein Distance. ADVANCES IN DATA ANALYSIS AND CLASSIFICATION, ISSN: 1862-5347, DOI:10.1007/s11634-015-0197-7

An extended version is available on arXiv repository arXiv:1202.1436v2 <http://arxiv.org/abs/1202.1436v2>

## Examples

```
# do regression
model.parameters=WH.regression.two.components(data = BLOOD,Yvar = 1, Xvars= c(2:3))
#' # do prediction
Predicted.BLOOD=WH.regression.two.components.predict(data = BLOOD[,2:3],parameters=model.parameters)
# compute GOF indices
GOF.indices=WH.regression.GOF(observed=BLOOD[,1], predicted=Predicted.BLOOD)
```

---

WH.regression.two.components

*Multiple regression analysis for histogram variables based on a two component model and L2 Wasserstein distance*

---

## Description

The function implements Multiple regression analysis for histogram variables based on a two component model and L2 Wasserstein distance. Taking as input dependent histogram variable and a set of explanatory histogram variables the methods return a least squares estimation of a two component regression model based on the decomposition of L2 Wasserstein metric for distributional data.

## Usage

```
WH.regression.two.components(data, Yvar, Xvars, simplify = FALSE,
  qua = 20)
```

## Arguments

data	A Math object (a matrix of distributionH).
Yvar	An integer, the dependent variable number in data.
Xvars	A set of integers the explanatory variables in data.
simplify	a logical argument (default=FALSE). If TRUE only few equally spaced quantiles are considered (for speeding up the algorithm)
qua	If simplify=TRUE is the number of quantiles to consider.

**Details**

A two component regression model is implemented. The observed variables are histogram variables according to the definition given in the framework of Symbolic Data Analysis and the parameters of the model are estimated using the classic Least Squares method. An appropriate metric is introduced in order to measure the error between the observed and the predicted distributions. In particular, the Wasserstein distance is proposed. Such a metric permits to predict the response variable as direct linear combination of other independent histogram variables.

**Value**

a named vector with the model estimated parameters

**References**

Irpino A, Verde R (in press 2015). Linear regression for numeric symbolic variables: a least squares approach based on Wasserstein Distance. ADVANCES IN DATA ANALYSIS AND CLASSIFICATION, ISSN: 1862-5347, DOI:10.1007/s11634-015-0197-7

An extended version is available on arXiv repository arXiv:1202.1436v2 <http://arxiv.org/abs/1202.1436v2>

**Examples**

```
model.parameters=WH.regression.two.components(data = BLOOD,Yvar = 1, Xvars= c(2:3))
```

---

```
WH.regression.two.components.predict
```

*Multiple regression analysis for histogram variables based on a two component model and L2 Wasserstein distance*

---

**Description**

Predict distributions using the results of a regression done with WH.regression.two.components function.

**Usage**

```
WH.regression.two.components.predict(data, parameters)
```

**Arguments**

data	A MatH object (a matrix of distributionH) explanatory part.
parameters	A named vector with the parameter from a WH.regression.two.components model

**Value**

a MatH object, the predicted histograms

## References

Irpino A, Verde R (in press 2015). Linear regression for numeric symbolic variables: a least squares approach based on Wasserstein Distance. *ADVANCES IN DATA ANALYSIS AND CLASSIFICATION*, ISSN: 1862-5347, DOI:10.1007/s11634-015-0197-7

An extended version is available on arXiv repository arXiv:1202.1436v2 <http://arxiv.org/abs/1202.1436v2>

## Examples

```
# do regression
model.parameters=WH.regression.two.components(data = BLOOD,Yvar = 1, Xvars= c(2:3))
# do prediction
Predicted.BLOOD=WH.regression.two.components.predict(data = BLOOD[,2:3],parameters=model.parameters)
```

---

WH.SSQ

*Method WH.SSQ*

---

## Description

Compute the sum-of-squares-deviations (from the mean) matrix of a Math object, i.e. a matrix of numbers, consistent with a set of distributions equipped with a L2 wasserstein metric.

## Usage

```
WH.SSQ(object, ...)
```

## S4 method for signature 'Math'

```
WH.SSQ(object, w = numeric(0))
```

## Arguments

object	a Math object
...	some optional parameters
w	it is possible to add a vector of weights (positive numbers) having the same size of the rows of the Math object, default = equal weight for each row

## Value

a squared matrix with the weighted sum of squares

## Examples

```
WH.SSQ(BLOOD)
# generate a set of random weights
RN<-runif(get.Math.nrows(BLOOD))
WH.SSQ(BLOOD,w=RN)
```

---

`WH.SSQ2`*Method WH.SSQ2*

---

### Description

Compute the sum-of-squares-deviations (from the mean) matrix using two `Math` objects having the same number of rows, It returns a rectangular a matrix of numbers, consistent with a set of distributions equipped with a L2 wasserstein metric.

### Usage

```
WH.SSQ2(object1, object2, ...)
```

```
## S4 method for signature 'Math,Math'
```

```
WH.SSQ2(object1, object2, w = numeric(0))
```

### Arguments

`object1` a `Math` object

`object2` a `Math` object

`...` some optional parameters

`w` it is possible to add a vector of weights (positive numbers) having the same size of the rows of the `Math` object, default = equal weight for each row

### Value

a rectangular matrix with the weighted sum of squares

### Examples

```
M1<-BLOOD[,1]
M2<-BLOOD[,2:3]
WH.SSQ2(M1,M2)
# generate a set of random weights
RN<-runif(get.Math.nrows(BLOOD))
WH.SSQ2(M1,M2,w=RN)
```

---

WH.var.covar	<i>Method WH.var.covar</i>
--------------	----------------------------

---

### Description

Compute the variance-covariance matrix of a Math object, i.e. a matrix of values consistent with a set of distributions equipped with a L2 wasserstein metric.

### Usage

```
WH.var.covar(object, ...)

## S4 method for signature 'Math'
WH.var.covar(object, w = numeric(0))
```

### Arguments

object	a Math object
...	some optional parameters
w	it is possible to add a vector of weights (positive numbers) having the same size of the rows of the Math object, default = equal weight for each row

### Value

a squared matrix with the (weighted) variance-covariance values

### References

Irpino, A., Verde, R. (2015) *Basic statistics for distributional symbolic variables: a new metric-based approach* Advances in Data Analysis and Classification, DOI 10.1007/s11634-014-0176-4

### Examples

```
WH.var.covar(BLOOD)
# generate a set of random weights
RN<-runif(get.Math.nrows(BLOOD))
WH.var.covar(BLOOD,w=RN)
```



---

WH.var.covar2	<i>Method WH.var.covar2</i>
---------------	-----------------------------

---

### Description

Compute the covariance matrix using two Math objects having the same number of rows, It returns a rectangular a matrix of numbers, consistent with a set of distributions equipped with a L2 wasserstein metric.

### Usage

```
WH.var.covar2(object1, object2, ...)
```

## S4 method for signature 'Math,Math'

```
WH.var.covar2(object1, object2, w = numeric(0))
```

### Arguments

object1	a Math object
object2	a Math object
...	some optional parameters
w	it is possible to add a vector of weights (positive numbers) having the same size of the rows of the Math object, default = equal weight for each row

### Value

a rectangular matrix with the weighted sum of squares

### Examples

```
M1<-BLOOD[,1]
M2<-BLOOD[,2:3]
WH.var.covar2(M1,M2)
# generate a set of random weights
RN<-runif(get.Math.nrows(BLOOD))
WH.var.covar2(M1,M2,w=RN)
```

---

WH.vec.mean	<i>Method WH.vec.mean</i>
-------------	---------------------------

---

**Description**

Compute a histogram that is the weighted mean of the set of histograms contained in a Math object, i.e. a matrix of histograms, consistent with a set of distributions equipped with a L2 wasserstein metric.

**Usage**

```
WH.vec.mean(object, ...)
```

```
## S4 method for signature 'Math'
```

```
WH.vec.mean(object, w = numeric(0))
```

**Arguments**

object	a Math object
...	optional arguments
w	it is possible to add a vector of weights (positive numbers) having the same size of the Math object, default = equal weights for all

**Value**

a distributionH object, i.e. a histogram

**Examples**

```
hmean<-WH.vec.mean(BLOOD)
```

```
# generate a set of random weights
```

```
RN<-runif(get.Math.nrows(BLOOD)*get.Math.ncols(BLOOD))
```

```
hmean<-WH.vec.mean(BLOOD,w=RN)
```

---

WH.vec.sum	<i>Method WH.vec.sum</i>
------------	--------------------------

---

**Description**

Compute a histogram that is the weighted sum of the set of histograms contained in a Math object, i.e. a matrix of histograms, consistent with a set of distributions equipped with a L2 wasserstein metric.

**Usage**

```
WH.vec.sum(object, ...)

## S4 method for signature 'Math'
WH.vec.sum(object, w = numeric(0))
```

**Arguments**

object	a Math object
...	optional arguments
w	it is possible to add a vector of weights (positive numbers) having the same size of the Math object, default = equal weights for all cells

**Value**

a distributionH object, i.e. a histogram

**Examples**

```
hsum<-WH.vec.sum(BLOOD)
# generate a set of random weights
RN<-runif(get.Math.nrows(BLOOD)*get.Math.ncols(BLOOD))
hsum<-WH.vec.sum(BLOOD,w=RN)
```

---

WH\_2d\_Adaptive\_Kohonen\_maps

*Batch Kohonen self-organizing 2d maps using adaptive distances for histogram-valued data*

---

**Description**

The function implements a Batch Kohonen self-organizing 2d maps algorithm for histogram-valued data.

**Usage**

```
WH_2d_Adaptive_Kohonen_maps(x, net = list(xdim = 4, ydim = 3, topo =
  c("rectangular")), kern.param = 2, TMAX = -9999, Tmin = -9999,
  niter = 30, repetitions, simplify = FALSE, qua = 10,
  standardize = FALSE, schema = 6, init.weights = "EQUAL",
  weight.sys = "PROD", theta = 2, Wfix = FALSE, verbose = FALSE,
  atleast = 2)
```

**Arguments**

<code>x</code>	A MatH object (a matrix of distributionH).
<code>net</code>	a list describing the topology of the net <code>list(xdim=number of rows,ydim=numbers of columns,topo=see somgrid syntax in packageclass default net=list(xdim=4,ydim=3,topo=c('rectangular'))</code>
<code>kern.param</code>	(default =2) the kernel parameter for the RBF kernel used in the algorithm
<code>TMAX</code>	a parameter useful for the iterations (default=2)
<code>Tmin</code>	a parameter useful for the iterations (default=0.2)
<code>niter</code>	maximum number of iterations (default=30)
<code>repetitions</code>	number of repetition of the algorithm (default=5), beacuse each launch may generate a local optimum
<code>simplify</code>	a logical parameter for speeding up computations (default=FALSE). If true data are recoded in order to have fast computations
<code>qua</code>	if <code>simplify=TRUE</code> number of equally spaced quantiles for recodify the histograms (default=10)
<code>standardize</code>	A logic value (default is FALSE). If TRUE, histogram-valued data are standardized, variable by variable, using the Wassertein based standard deviation. Use if one wants to have variables with std equal to one.
<code>schema</code>	a number from 1 to 4 1=A weight for each variable (default) 2=A weight for the average and the dispersion component of each variable 3=Same as 1 but a different set of weights for each cluster 4=Same as 2 but a different set of weights for each cluster
<code>init.weights</code>	a string how to initialize weights: 'EQUAL' (default), all weights are the same,
<code>weight.sys</code>	a string. Weights may add to one ('SUM') or their product is equal to 1 ('PROD', default).
<code>theta</code>	a number. A parameter if <code>weight.sys='SUM'</code> , default is 2.
<code>Wfix</code>	a logical parameter (default=FALSE). If TRUE the algorithm does not use adaptive distances.
<code>verbose</code>	a logical parameter (default=FALSE). If TRUE details of computation are shown during the execution. #'
<code>atleast</code>	integer. Check for degeneration of the map into a very low number of voronoi sets. (default 2) 2 means that the map will have at least 2 neurons attracting data instances in their voronoi sets.

**Details**

An extension of Batch Self Organised Map (BSOM) is here proposed for histogram data. These kind of data have been defined in the context of symbolic data analysis. The BSOM cost function is then based on a distance function: the L2 Wasserstein distance. This distance has been widely proposed in several techniques of analysis (clustering, regression) when input data are expressed by distributions (empirical by histograms or theoretical by probability distributions). The peculiarity of such distance is to be an Euclidean distance between quantile functions so that all the properties proved for L2 distances are verified again. An adaptative versions of BSOM is also introduced considering an automatic system of weights in the cost function in order to take into account the different effect of the several variables in the Self-Organised Map grid.

**Value**

a list with the results of the Batch Kohonen map

**Slots**

`solution` A list. Returns the best solution among the repetitionsetitions, i.e. the one having the minimum sum of squares criterion.

`solution$MAP` The map topology.

`solution$IDX` A vector. The clusters at which the objects are assigned.

`solution$cardinality` A vector. The cardinality of each final cluster.

`solution$proto` A `Math` object with the description of centers.

`solution$Crit` A number. The criterion (Sum od square deviation from the centers) value at the end of the run.

`solution$Weights.comp` the final weights assigned to each component of the histogram variables

`solution$Weight.sys` a string the type of weighting system ('SUM' or 'PRODUCT')

`quality` A number. The percentage of Sum of square deviation explained by the model. (The higher the better)

**References**

Irpino A, Verde R, De Carvalho FAT (2012). Batch self organizing maps for interval and histogram data. In: Proceedings of COMPSTAT 2012. p. 143-154, ISI/IASC, ISBN: 978-90-73592-32-2

**Examples**

```
## Not run:
results=WH_2d_Adaptive_Kohonen_maps(x = BLOOD,
                                   net=list(xdim=2,ydim=3,topo=c('rectangular')),
                                   repetitions = 2,simplify = TRUE,
                                   qua = 10,standardize = TRUE)

## End(Not run)
```

---

WH\_2d\_Kohonen\_maps      *Batch Kohonen self-organizing 2d maps for histogram-valued data*

---

**Description**

The function implements a Batch Kohonen self-organizing 2d maps algorithm for histogram-valued data.

**Usage**

```
WH_2d_Kohonen_maps(x, net = list(xdim = 4, ydim = 3, topo =
  c("rectangular")), kern.param = 2, TMAX = 2, Tmin = 0.2,
  niter = 30, repetitions = 5, simplify = FALSE, qua = 10,
  standardize = FALSE, verbose = FALSE)
```

**Arguments**

<code>x</code>	A <code>MatH</code> object (a matrix of distributionH).
<code>net</code>	a list describing the topology of the net <code>list(xdim=number of rows,ydim=numbers of columns,topo=see songrid syntax in packageclass default net=list(xdim=4,ydim=3,topo=c('rectangular'))</code>
<code>kern.param</code>	(default =2) the kernel parameter for the RBF kernel used in the algorithm
<code>TMAX</code>	a parameter useful for the iterations (default=2)
<code>Tmin</code>	a parameter useful for the iterations (default=0.2)
<code>niter</code>	maximum number of iterations (default=30)
<code>repetitions</code>	number of repetition of the algorithm (default=5), beacuse each launch may generate a local optimum
<code>simplify</code>	a logical parameter for speeding up computations (default=FALSE). If true data are recoded in order to have fast computations
<code>qua</code>	if <code>simplify=TRUE</code> number of equally spaced quantiles for recodify the histograms (default=10)
<code>standardize</code>	A logic value (default is FALSE). If TRUE, histogram-valued data are standardized, variable by variable, using the Wassertein based standard deviation. Use if one wants to have variables with std equal to one.
<code>verbose</code>	a logical parameter (default=FALSE). If TRUE details of computation are shown during the execution.

**Details**

An extension of Batch Self Organised Map (BSOM) is here proposed for histogram data. These kind of data have been defined in the context of symbolic data analysis. The BSOM cost function is then based on a distance function: the L2 Wasserstein distance. This distance has been widely proposed in several techniques of analysis (clustering, regression) when input data are expressed by distributions (empirical by histograms or theoretical by probability distributions). The peculiarity of such distance is to be an Euclidean distance between quantile functions so that all the properties proved for L2 distances are verified again. An adaptative versions of BSOM is also introduced considering an automatic system of weights in the cost function in order to take into account the different effect of the several variables in the Self-Organised Map grid.

**Value**

a list with the results of the Batch Kohonen map

**Slots**

`solution` A list>Returns the best solution among the repetitionsetitions, i.e. the one having the minimum sum of squares criterion.

`solution$MAP` The map topology.

`solution$IDX` A vector. The clusters at which the objects are assigned.

`solution$cardinality` A vector. The cardinality of each final cluster.

`solution$proto` A `MatH` object with the description of centers.

`solution$Crit` A number. The criterion (Sum of square deviation from the centers) value at the end of the run.

`quality` A number. The percentage of Sum of square deviation explained by the model. (The higher the better)

## References

Irpino A, Verde R, De Carvalho FAT (2012). Batch self organizing maps for interval and histogram data. In: Proceedings of COMPSTAT 2012. p. 143-154, ISI/IASC, ISBN: 978-90-73592-32-2

## Examples

```
## Not run:
results=WH_2d_Kohonen_maps(x = BLOOD,
                           net=list(xdim=2,ydim=3,topo=c('rectangular')),
                           repetitions = 2,simplify = TRUE,
                           qua = 10,standardize = TRUE)

## End(Not run)
```

---

WH_adaptive.kmeans	<i>K-means of a dataset of histogram-valued data using adaptive Wasserstein distances</i>
--------------------	---

---

## Description

The function implements the k-means using adaptive distance for a set of histogram-valued data.

## Usage

```
WH_adaptive.kmeans(x, k, schema = 1, init, rep, simplify = FALSE,
                   qua = 10, standardize = FALSE, weight.sys = "PROD", theta = 2,
                   init.weights = "EQUAL", verbose = FALSE)
```

## Arguments

<code>x</code>	A Math object (a matrix of distributionH).
<code>k</code>	An integer, the number of groups.
<code>schema</code>	a number from 1 to 4 1=A weight for each variable (default) 2=A weight for the average and the dispersion component of each variable 3=Same as 1 but a different set of weights for each cluster 4=Same as 2 but a different set of weights for each cluster
<code>init</code>	(optional, do not use) initialization for partitioning the data default is 'RPART', other strategies should be implemented.
<code>rep</code>	An integer, maximum number of repetitions of the algorithm (default rep=5).

simplify	A logic value (default is FALSE), if TRUE histograms are recomputed in order to speed-up the algorithm.
qua	An integer, if simplify=TRUE is the number of quantiles used for recodify the histograms.
standardize	A logic value (default is FALSE). If TRUE, histogram-valued data are standardized, variable by variable, using the Wasserstein based standard deviation. Use if one wants to have variables with std equal to one.
weight.sys	a string. Weights may add to one ('SUM') or their product is equal to 1 ('PROD', default).
theta	a number. A parameter if weight.sys='SUM', default is 2.
init.weights	a string how to initialize weights: 'EQUAL' (default), all weights are the same, 'RANDOM', weights are initialised at random.
verbose	A logic value (default is FALSE). If TRUE, details on computations are shown.

### Value

a list with the results of the k-means of the set of Histogram-valued data x into k cluster.

### Slots

- solution A list. Returns the best solution among the repetitions, i.e. the one having the minimum sum of squares criterion.
- solution\$IDX A vector. The clusters at which the objects are assigned.
- solution\$cardinality A vector. The cardinality of each final cluster.
- solution\$centers A Math object with the description of centers.
- solution\$Crit A number. The criterion (Sum of square deviation from the centers) value at the end of the run.
- quality A number. The percentage of Sum of square deviation explained by the model. (The higher the better)

### References

Irpino A., Rosanna V., De Carvalho F.A.T. (2014). Dynamic clustering of histogram data based on adaptive squared Wasserstein distances. EXPERT SYSTEMS WITH APPLICATIONS, vol. 41, p. 3351-3366, ISSN: 0957-4174, doi: <http://dx.doi.org/10.1016/j.eswa.2013.12.001>

### Examples

```
results=WH_adaptive.kmeans(x = BLOOD,k = 2, rep = 10,simplify = TRUE,qua = 10,standardize = TRUE)
```



---

WH\_adaptive\_fcmeans     *Fuzzy c-means with adaptive distances for histogram-valued data*

---

### Description

Fuzzy c-means of a dataset of histogram-valued data using different adaptive distances based on the L2 Wasserstein metric.

### Usage

```
WH_adaptive_fcmeans(x, k = 5, schema, m = 1.6, rep, simplify = FALSE,
  qua = 10, standardize = FALSE, init.weights = "EQUAL",
  weight.sys = "PROD", theta = 2, verbose = FALSE)
```

### Arguments

x	A Math object (a matrix of distributionH).
k	An integer, the number of groups.
schema	An integer. 1=one weight per variable, 2=two weights per variables (one for each component: the mean and the variability component), 3=one weight per variable and per cluster, 4= two weights per variable and per cluster.
m	A number greater than 0, a fuzziness coefficient (default m=1.6).
rep	An integer, maximum number of repetitions of the algorithm (default rep=5).
simplify	A logic value (default is FALSE), if TRUE histograms are recomputed in order to speed-up the algorithm.
qua	An integer, if simplify=TRUE is the number of quantiles used for recodify the histograms.
standardize	A logic value (default is FALSE). If TRUE, histogram-valued data are standardized, variable by variable, using the Wasserstein based standard deviation. Use if one wants to have variables with std equal to one.
init.weights	A string. (default='EQUAL'). EQUAL, all variables or components have the same weight; 'RANDOM', a random assignment is done.
weight.sys	A string. (default='PROD') PROD, Weights product is equal to one. SUM, the weights sum up to one.
theta	A number. (default=2) A parameter for the system of weights summing up to one.
verbose	A logic value (default is FALSE). If TRUE some details are provided.

### Value

The results of the fuzzy c-means of the set of Histogram-valued data x into k cluster.

solution	A list>Returns the best solution among the repetitions, i.e. the one having the minimum sum of squares deviation.
----------	---

<code>solution\$membership</code>	A matrix. The membership degree of each unit to each cluster.
<code>solution\$IDX</code>	A vector. The crisp assignment to a cluster.
<code>solution\$cardinality</code>	A vector. The cardinality of each final cluster (after the crisp assignment).
<code>solution\$Crit</code>	A number. The criterion (Sum of square deviation from the prototypes) value at the end of the run.
<code>quality</code>	A number. The percentage of Sum of square deviation explained by the model. (The higher the better)

### Examples

```
results=WH_adaptive_fcmeans(x = BLOOD,k = 2,schema=4,m = 1.5,rep = 3,simplify = TRUE,
                             qua = 10,standardize = TRUE,init.weights='EQUAL', weight.sys='PROD')
```

---

WH_fcmeans	<i>Fuzzy c-means of a dataset of histogram-valued data</i>
------------	--

---

### Description

The function implements the fuzzy c-means for a set of histogram-valued data.

### Usage

```
WH_fcmeans(x, k, m = 1.6, rep, simplify = FALSE, qua = 10,
            standardize = FALSE)
```

### Arguments

<code>x</code>	A MatH object (a matrix of distributionH).
<code>k</code>	An integer, the number of groups.
<code>m</code>	A number greater than 0, a fuzziness coefficient (default $m=1.6$ ).
<code>rep</code>	An integer, maximum number of repetitions of the algorithm (default $rep=5$ ).
<code>simplify</code>	A logic value (default is FALSE), if TRUE histograms are recomputed in order to speed-up the algorithm.
<code>qua</code>	An integer, if <code>simplify=TRUE</code> is the number of quantiles used for recodify the histograms.
<code>standardize</code>	A logic value (default is FALSE). If TRUE, histogram-valued data are standardized, variable by variable, using the Wassertein based standard deviation. Use if one wants to have variables with std equal to one.

### Value

a list with the results of the fuzzy c-means of the set of Histogram-valued data `x` into `k` cluster.

**Slots**

- `solution` A list. Returns the best solution among the repetitions, i.e. the one having the minimum sum of squares deviation.
- `solution$membership` A matrix. The membership degree of each unit to each cluster.
- `solution$IDX` A vector. The crisp assignement to a cluster.
- `solution$cardinality` A vector. The cardinality of each final cluster (after the crisp assignement).
- `solution$Crit` A number. The criterion (Sum of square deviation from the prototypes) value at the end of the run.
- `quality` A number. The percentage of Sum of square deviation explained by the model. (The higher the better)

**Examples**

```
results=WH_fcmeans(x = BLOOD,k = 2,m = 1.5,rep = 10,simplify = TRUE,qua = 10,standardize = TRUE)
```

---

 WH\_hclust

*Hierarchical clustering of histogram data*


---

**Description**

The function implements a Hierarchical clustering for a set of histogram-valued data, based on the L2 Wassertein distance. Extends the `hclust` function of the **stat** package.

**Usage**

```
WH_hclust(x, simplify = FALSE, qua = 10, standardize = FALSE,
  distance = "WDIST", method = "complete")
```

**Arguments**

- |                          |  |
|--------------------------|--|
| <code>x</code>           | A Math object (a matrix of distributionH).   |
| <code>simplify</code>    | A logic value (default is FALSE), if TRUE histograms are recomputed in order to speed-up the algorithm.  |
| <code>qua</code>         | An integer, if <code>simplify=TRUE</code> is the number of quantiles used for recodify the histograms.   |
| <code>standardize</code> | A logic value (default is FALSE). If TRUE, histogram-valued data are standardized, variable by variable, using the Wassertein based standard deviation. Use if one wants to have variables with std equal to one.  |
| <code>distance</code>    | A string default "WDIST" the L2 Wasserstein distance (other distances will be implemented)   |
| <code>method</code>      | A string, default="complete", is the the agglomeration method to be used. This should be (an unambiguous abbreviation of) one of "ward.D", "ward.D2", "single", "complete", "average" (= UPGMA), "mcquitty" (= WPGMA), "median" (= WPGMC) or "centroid" (= UPGMC). |

**Value**

An object of class `hclust` which describes the tree produced by the clustering process.

**References**

Irpino A., Verde R. (2006). A new Wasserstein based distance for the hierarchical clustering of histogram symbolic data. In: Batanjeli et al. Data Science and Classification, IFCS 2006. p. 185-192, BERLIN:Springer, ISBN: 3-540-34415-2

**See Also**

`hclust` of `stat` package for further details.

**Examples**

```
results=WH_hclust(x = BLOOD,simplify = TRUE, method="complete")
plot(results) # it plots the dendrogram
cutree(results,k = 5) # it returns the labels for 5 clusters
```

---

WH\_kmeans

*K-means of a dataset of histogram-valued data*

---

**Description**

The function implements the k-means for a set of histogram-valued data.

**Usage**

```
WH_kmeans(x, k, rep = 5, simplify = FALSE, qua = 10,
          standardize = FALSE, verbose = FALSE)
```

**Arguments**

<code>x</code>	A <code>Math</code> object (a matrix of distributionH).
<code>k</code>	An integer, the number of groups.
<code>rep</code>	An integer, maximum number of repetitions of the algorithm (default <code>rep=5</code> ).
<code>simplify</code>	A logic value (default is <code>FALSE</code> ), if <code>TRUE</code> histograms are recomputed in order to speed-up the algorithm.
<code>qua</code>	An integer, if <code>simplify=TRUE</code> is the number of quantiles used for recodify the histograms.
<code>standardize</code>	A logic value (default is <code>FALSE</code> ). If <code>TRUE</code> , histogram-valued data are standardized, variable by variable, using the Wasserstein based standard deviation. Use if one wants to have variables with std equal to one.
<code>verbose</code>	A logic value (default is <code>FALSE</code> ). If <code>TRUE</code> , details on computations are shown.

**Value**

a list with the results of the k-means of the set of Histogram-valued data x into k cluster.

**Slots**

`solution` A list. Returns the best solution among the repetitions, i.e. the one having the minimum sum of squares criterion.

`solution$IDX` A vector. The clusters at which the objects are assigned.

`solution$cardinality` A vector. The cardinality of each final cluster.

`solution$centers` A Math object with the description of centers.

`solution$Crit` A number. The criterion (Sum of square deviation from the centers) value at the end of the run.

`quality` A number. The percentage of Sum of square deviation explained by the model. (The higher the better)

**References**

Irpino A., Verde R., Lechevallier Y. (2006). Dynamic clustering of histograms using Wasserstein metric. In: Rizzi A., Vichi M.. COMPSTAT 2006 - Advances in computational statistics. p. 869-876, Heidelberg:Physica-Verlag

**Examples**

```
results=WH_kmeans(x = BLOOD,k = 2, rep = 10,simplify = TRUE,
qua = 10,standardize = TRUE,verbose=TRUE)
```

---

[ *extract from a Math Method* ]

---

**Description**

This method overrides the "[" operator for a math object.

**Usage**

```
## S4 method for signature 'Math'
x[i, j, ..., drop = TRUE]
```

**Arguments**

x	a math object
i	a set of integer values identifying the rows
j	a set of integer values identifying the columns
...	not useful
drop	a logical value inherited from the basic method "[" but not used (default=TRUE)

**Value**

A math object

**Examples**

```
D=BLOOD #the BLOOD dataset  
SUB_D=BLOOD[c(1,2,5),c(1,2)]
```

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