Package 'EHRtemporalVariability'

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Type Package

Title Delineating Temporal Dataset Shifts in Electronic Health Records

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Description Functions to delineate temporal dataset shifts in Electronic Health Records through the projection and visualization of dissimilarities among data temporal batches. This is done through the estimation of data statistical distributions over time and their projection in non-parametric statistical manifolds, uncovering the patterns of the data latent temporal variability. 'EHRtemporalVariability' is particularly suitable for multi-modal data and categorical variables with a high number of values, common features of biomedical data where traditional statistical process control or time-series methods may not be appropriate. 'EHRtemporalVariability' allows you to explore and identify dataset shifts through visual analytics formats such as Data Temporal heatmaps and Information Geometric Temporal (IGT) plots. An additional 'EHRtemporalVariability' Shiny app can be used to load and explore the package results and even to allow the use of these functions to those users non-experienced in R coding. (Sáez et al. 2020) <doi:10.1093/gigascience/giaa079>.

Depends R (>= 4.3.0), dplyr

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Imports plotly, zoo, xts, lubridate, RColorBrewer, viridis, scales, methods, MASS

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NeedsCompilation no

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Contents

DataTemporalMap-class . . . 2
estimateDataTemporalMap . . . 3
estimateIGTProjection . . . 5
estimateIGTTrajectory . . . 7
formatDate . . . 7
icd9toPheWAS . . . 8
IGTProjection-class . . . 9
plotDataTemporalMap . . . 10
plotIGTProjection . . . 12
trimDataTemporalMap . . . 14

Index **15**

`DataTemporalMap-class` *Class DataTemporalMap*

Description

Class `DataTemporalMap` object contains the statistical distributions of data estimated at a specific time period. Both relative and absolute frequencies are included.

Details

Objects of this class are generated automatically by the `estimateDataTemporalMap` function, but its construction and extension is open towards fostering its use through external methods. E.g., one may use additional probability distribution estimation methods, or even construct compatible DataTemporalMaps for other unstructured data such as images or free text.

Value

A `DataTemporalMap` object.

Slots

`probabilityMap` v-by-d numerical `matrix` representing the probability distribution temporal map (relative frequency).

`countsMap` v-by-d numerical `matrix` representing the counts temporal map (absolute frequency).

`dates` d-dimensional `Date` array of the temporal batches.

`support` v-by-1 numerical or character `matrix` representing the support (the value at each bin) of probabilityMap and countsMap.

`variableName` name of the variable (character).

`variableType` type of the variable (character) among "numeric", "character", "Date" and "factor".

`period` batching period among "week", "month" and "year".

Examples

```
# Generation through estimateDataTemporalMap function:
dataset <- read.csv2(xzfile(system.file("extdata",
                                "nhdsSubset.csv.xz",
                                package="EHRtemporalVariability")),
                     sep  = ",",
                     header = TRUE,
                     na.strings = "",
                     colClasses = c( "character", "numeric", "factor",
                                     "numeric" , rep( "factor", 22 ) ) )

datasetFormatted <- EHRtemporalVariability::formatDate(
                     input         = dataset,
                     dateColumn    = "date",
                     dateFormat = "%y/%m")

probMaps <- estimateDataTemporalMap(data = datasetFormatted,
                     dateColumnName = "date",
                     period         = "month")

class( probMaps[[1]] )

# Manual generation:
countsMatrix <- matrix(sample.int(25, size = 12*10, replace = TRUE), nrow = 12, ncol = 10)
probabilityMatrix <- sweep(countsMatrix,1,rowSums(countsMatrix),"/")
dates <- seq(Sys.Date(),(Sys.Date()+30*11),30)
x <- new('DataTemporalMap', probabilityMap = probabilityMatrix,
                    countsMap = countsMatrix, dates = dates, support = data.frame(1:10),
                   variableName = "example", variableType = "numeric", period = "month")
plotDataTemporalMap(x)
```

`estimateDataTemporalMap`

Estimates `DataTemporalMap` *objects from raw data*

Description

Estimates a `DataTemporalMap` from a `data.frame` containing individuals in rows and the variables in columns, being one of these columns the analysis date (typically the acquisition date). Will return a `DataTemporalMap` object or a `list` of `DataTemporalMap` objects depending on the number of analysis variables.

Usage

```
estimateDataTemporalMap(
  data = NULL,
  dateColumnName = NULL,
  period = "month",
  startDate = NULL,
  endDate = NULL,
  supports = NULL,
  numericVariablesBins = 100,
```

```
  numericSmoothing = TRUE,
  dateGapsSmoothing = FALSE,
  verbose = FALSE
)
```

Arguments

data	a data.frame containing as many rows as individuals, and as many columns as the analysis variables plus the individual acquisition date.
dateColumnName	a string indicating the name of the column in data containing the analysis date variable.
period	the period at which to batch data for the analysis from "week", "month" and "year", with "month" as default.
startDate	a Date object indicating the date at which to start the analysis, in case of being different from the first chronological date in the date column (the default).
endDate	a Date object indicating the date at which to end the analysis, in case of being different from the last chronological date in the date column (the default).
supports	a List of objects containing the support of the data distributions for each variable, in classes numeric, integer, character, or factor (accordingly to the variable type), and where the name of the list element must correspond to the column name of its variable. If not provided it is automatically estimated from data.
numericVariablesBins	the number of bins at which to define the frequency/density histogram for numerical variables when their support is not provided, 100 as default.
numericSmoothing	a logical value indicating whether a Kernel Density Estimation smoothing (Gaussian kernel, default bandwidth) is to be applied on numerical variables (the default) or a traditional histogram instead. See ?density for further details.
dateGapsSmoothing	a logical value indicating whether a linear smoothing is applied to those time batches without data, by default gaps are filled with NAs.
verbose	By default FALSE. Change it to TRUE to get an on-time log from the function.

Value

A DataTemporalMap object.

Examples

```
#Load the file
dataset <- read.csv2(xzfile(system.file("extdata",
                                    "nhdsSubset.csv.xz",
                                    package="EHRtemporalVariability")),
                     sep  = ",",
                     header = TRUE,
                     na.strings = "",
                     colClasses = c( "character", "numeric", "factor",
                                     "numeric" , rep( "factor", 22 ) ) )
#Format the date
datasetFormatted <- EHRtemporalVariability::formatDate( input         = dataset,
                                            dateColumn    = "date",
```

```
                                          dateFormat    = "%y/%m")

#Apply the estimateDataTemporalMap
probMaps <- estimateDataTemporalMap( data           = datasetFormatted,
                                     dateColumnName = "date",
                                     period         = "month")
## Not run:

For a larger example download the following .csv dataset and continue the steps as above:

gitHubUrl  <- 'http://github.com/'
gitHubPath <- 'hms-dbmi/EHRtemporalVariability-DataExamples/'
gitHubFile <- 'raw/master/nhdsSubset.csv'
inputFile  <-  paste0(gitHubUrl, gitHubPath, gitHubFile)

dataset <- read.csv2( inputFile,
                      sep  = ",",
                      header = TRUE,
                      na.strings = "",
                      colClasses = c( "character", "numeric", "factor",
                                      "numeric" , rep( "factor", 22 ) ) )

## End(Not run)
```

`estimateIGTProjection` *Estimates an Information Geometric Temporal plot projection*

Description

Estimates an `IGTProjection` object from a `DataTemporalMap` object.

Usage

```
estimateIGTProjection(
  dataTemporalMap,
  dimensions = 3,
  startDate = NULL,
  endDate = NULL,
  embeddingType = "classicalmds"
)

## S4 method for signature 'DataTemporalMap'
estimateIGTProjection(
  dataTemporalMap,
  dimensions = 3,
  startDate = NULL,
  endDate = NULL,
  embeddingType = "classicalmds"
)
```

Arguments

dataTemporalMap	of class DataTemporalMap object.
dimensions	numeric integer value indicating the number of dimensions for the projection.
startDate	a Date object indicating the date at which to start the analysis, in case of being different from the first chronological date in the date column (the default).
endDate	a Date object indicating the date at which to end the analysis, in case of being different from the last chronological date in the date column (the default).
embeddingType	the type of embedding to apply to the dissimilarity matrix of time batches in order to obtain the non-parametric Statistical Manifold, from "classicalmds" and "nonmetricmds", with "classicalmds" as default. "classicalmds" uses the base R stats::cmdscale function, while "nonmetricmds" uses the MASS:isoMDS function. The returned stress format will depend on the selected embedding type: "classicalmds" returns 1-GOF as returned by stats::cmdscale function, "nonmetricmds" returns the final stress in percent, as returned by the MASS::isoMDS function

Value

An IGTProjection object containing the projected coordinates of each temporal batch in the embedded non-parametric Statistical Manifold, as well as the embedding stress according to the embeddingType.

Examples

```
load(system.file("extdata",
                 "variabilityDemoNHDSdiagcode1-phewascode.RData",
                  package="EHRtemporalVariability"))
igtProj <- estimateIGTProjection( dataTemporalMap = probMaps$`diagcode1-phewascode`,
dimensions      = 3,
startDate       = "2000-01-01",
endDate         = "2010-12-31")

## Not run:

# For additional and larger examples download the following .Rdata file:

gitHubUrl  <- 'http://github.com/'
gitHubPath <- 'hms-dbmi/EHRtemporalVariability-DataExamples/'
gitHubFile <- 'raw/master/variabilityDemoNHDS.RData'
inputFile  <-  paste0(gitHubUrl, gitHubPath, gitHubFile)

load(url(inputFile))
igtProj <- estimateIGTProjection( dataTemporalMap = probMaps[[1]],
dimensions      = 3,
startDate       = "2000-01-01",
endDate         = "2010-12-31")

## End(Not run)
```

estimateIGTTrajectory *Estimates a trajectory of the information temporal evolution in a IGT projection by fitting a cubic smoothing spline*

Description

Estimates a DataTemporalMap from a data.frame containing individuals in rows and the variables in columns, being one of these columns the analysis date (typically the acquisition date). Will return a DataTemporalMap object or a list of DataTemporalMap objects depending on the number of analysis variables.

Usage

```
estimateIGTTrajectory(igtProjection, nPoints = NULL)
```

Arguments

igtProjection	of class IGTProjection.
nPoints	the number of points to fit within the IGT projection range. By default 10x the number of time batches, what shows a high resolution trajectory.

Value

A list containing a data.frame of the estimated trajectory points, the estimated date for each point, and the fitted trajectory function as smooth.spline objects.

Examples

```
load(system.file("extdata",
                 "variabilityDemoNHDSdiagcode1-phewascode.RData",
                  package="EHRtemporalVariability"))

igtTrajectory <- estimateIGTTrajectory( igtProjection   =  igtProjs[[1]] )
igtTrajectory$points
```

formatDate *Function to transform dates into "Date" R format*

Description

Given a data.frame object with a column of dates in 'character' format, it generates a new data.frame object with the dates transformed into "Date" R format.

Usage

```
formatDate(input, dateColumn, dateFormat = "%y/%m/%d", verbose = FALSE)
```

Arguments

input	A data.frame object with at least one column of dates.
dateColumn	The name of the column containing the date.
dateFormat	By default '%y/%m/%d'. Change it to the specific structure of your date format.
verbose	By default FALSE. Change it to TRUE to get an on-time log from the function.

Value

An object of class data.frame with the date column transform into 'Date' R class.

Examples

```
dataset <- read.csv2(xzfile(system.file("extdata",
                                    "nhdsSubset.csv.xz",
                                    package="EHRtemporalVariability")),
                     sep  = ",",
                     header = TRUE,
                     na.strings = "",
                     colClasses = c( "character", "numeric", "factor",
                                     "numeric" , rep( "factor", 22 ) ) )

datasetFormatted <- formatDate(
              input         = dataset,
              dateColumn    = "date",
              dateFormat    = "%y/%m",
             )
```

---

icd9toPheWAS *Function to transform ICD9-CM codification into PheWAS code*

Description

Given a data.frame object with a column of ICD9-CM codes, it generates a new data.frame object with the ICD9-CM codes transformed into PheWAS codes.

Usage

```
icd9toPheWAS(
  data,
  icd9ColumnName,
  missingValues = "NA",
  phecodeDescription = FALSE,
  statistics = FALSE,
  replaceColumn = TRUE,
  verbose = FALSE
)
```

Arguments

data	A data.frame object with at least one column of ICD9-CM codes that one to be transformed into a PheWAS code.
icd9ColumnName	The name of the column containing the ICD9-CM.
missingValues	The value used to determine missing values in the data.frame.
phecodeDescription	By default FALSE. Change it to TRUE to map to the PheWAS code description instead to the PheWAS numeric code.
statistics	By default FALSE. Change it to TRUE to show the summary of the mapping like the percentage of initial ICD9-CM codes mapped to PheWAS code.
replaceColumn	By default TRUE. Change it to FALSE in order to create a new column with the PheWAS code maintaining the ICD9-CM code.
verbose	By default FALSE. Change it to TRUE to get an on-time log from the function.

Value

An object of class data.frame with the ICD9-CM column transform into PheWAS codes.

Examples

```
dataset <- read.csv2(xzfile(system.file("extdata",
                                    "nhdsSubset.csv.xz",
                                    package="EHRtemporalVariability")),
                     sep  = ",",
                     header = TRUE,
                     na.strings = "",
                     colClasses = c( "character", "numeric", "factor",
                                     "numeric" , rep( "factor", 22 ) ) )

datasetPheWAS <- icd9toPheWAS( data           = dataset,
                               icd9ColumnName  = "diagcode1",
                               missingValues   = "N/A",
                               replaceColumn   = TRUE,
                               statistics      = TRUE
                               )
```

IGTProjection-class *Class IGTProjection*

Description

Class IGTProjection object contains the estimated Information Geometric Temporal plot projection of a DataTemporalMap object.

Details

Objects of this class are generated automatically by the estimateIGTProjection function, and can be passed to the plotIGTProjection function for plotting the Information Geometric Temporal plot.

Value

A IGTProjection object.

Slots

dataTemporalMap the DataTemporalMap object from which the projection was estimated

projection d-by-c matrix of the IGT projection for d temporal batches in c dimensions calculated from the estimateIGTProjection function

embeddingType embedding function used for the IGT projection calculation in the estimateIGTProjection function

stress stress achieved in the lower-dimensional embedding, depending on the embedding type (e.g., classicalmds will return 1-GOF as returned by stats::cmdscale function, and nonmetricmds will return final stress in percent, as returned by the MASS::isoMDS function)

---

plotDataTemporalMap *Data Temporal heatmap*

Description

Plots a Data Temporal heatmap from an DataTemporalMap object.

Usage

```
plotDataTemporalMap(
  dataTemporalMap,
  absolute = FALSE,
  startValue = 1,
  endValue = ncol(dataTemporalMap@probabilityMap),
  startDate = min(dataTemporalMap@dates),
  endDate = max(dataTemporalMap@dates),
  sortingMethod = "frequency",
  colorPalette = "Spectral",
  mode = "heatmap"
)

## S4 method for signature 'DataTemporalMap'
plotDataTemporalMap(
  dataTemporalMap,
  absolute = FALSE,
  startValue = 1,
  endValue = ncol(dataTemporalMap@probabilityMap),
  startDate = min(dataTemporalMap@dates),
  endDate = max(dataTemporalMap@dates),
  sortingMethod = "frequency",
  colorPalette = "Spectral",
  mode = "heatmap"
)
```

Arguments

dataTemporalMap	of class DataTemporalMap
absolute	indicates if the heatmap frequency values are absolute or relative. By default FALSE.
startValue	indicates the first value to display in the heatmap. By default 1.
endValue	indicates the last value to display in the heatmap. By default the last value of the DataTemporalMap object.
startDate	a Date object indicating the first date to be displayed in the heatmap. By default the first date of the DataTemporalMap object.
endDate	a Date object indicating the last date to be displayed in the heatmap. By default the last date of the DataTemporalMap object.
sortingMethod	the method to sort data in the Y axis of the heatmap from "frequency" and "alphabetical", with "frequency" as default.
colorPalette	color palette to be used. The default "Spectral" palette shows a color temperature scheme from blue, through yellow, to red (see "Spectral" palette in RColorBrewer package). The four remaining options are better suited for those with colorblindness, including "Viridis", "Magma", and their reversed versions "Viridis-reversed" and "Magma-reversed" (see "Viridis" and "Magma" palettes in the Viridis package).
mode	indicates the plot mode as a 'heatmap' (default) or 'series'. The other config parameters for the heatmap plot also apply for the series plot.

Value

A plot object based on the plotly package.

Examples

```
load(system.file("extdata",
                 "variabilityDemoNHDSdiagcode1-phewascode.RData",
                  package="EHRtemporalVariability"))

p <- plotDataTemporalMap(dataTemporalMap =  probMaps[[1]],
                    colorPalette    = "Spectral",
                    startValue = 2,
                    endValue = 40)
p

p <- plotDataTemporalMap(dataTemporalMap =  probMaps[[1]],
                    colorPalette    = "Spectral",
                    startValue = 2,
                    endValue = 40,
                    mode = "series")
p

## Not run:

# For additional and larger examples download the following .Rdata file:

gitHubUrl  <- 'http://github.com/'
gitHubPath <- 'hms-dbmi/EHRtemporalVariability-DataExamples/'
```

```
gitHubFile <- 'raw/master/variabilityDemoNHDS.RData'
inputFile  <-  paste0(gitHubUrl, gitHubPath, gitHubFile)

load(url(inputFile))
plotDataTemporalMap(probMaps$`diagcode1-phewascode`, startValue = 2, endValue = 40)

## End(Not run)
```

`plotIGTProjection` *Information Geometric Temporal plot*

Description

Plots an interactive Information Geometric Temporal (IGT) plot from an `IGTProjection` object. An IGT plot visualizes the variability among time batches in a data repository in a 2D or 3D plot. Time batches are positioned as points where the distance between them represents the probabilistic distance between their distributions (currently Jensen-Shannon distance, more distances will be supported in the future). To track the temporal evolution, temporal batches are labeled to show their date and colored according to their season or period, according to the analysis period, as follows. If period=="year" the label is "yy" (2 digit year) and the color is according to year. If period=="month" the label is "yym" (yy + abbreviated month*) and the color is according to the season (yearly). If period=="week" the label is "yymmw" (yym + ISO week number in 1-2 digit) and the color is according to the season (yearly). An estimated smoothed trajectory of the information evolution over time can be shown using the optional "trajectory" parameter. *Month abbreviations: {'J', 'F', 'M', 'A', 'm', 'j', 'x', 'a', 'S', 'O', 'N', 'D'}.

Usage

```
plotIGTProjection(
  igtProjection,
  dimensions = 3,
  startDate = min(igtProjection@dataTemporalMap@dates),
  endDate = max(igtProjection@dataTemporalMap@dates),
  colorPalette = "Spectral",
  trajectory = FALSE
)

## S4 method for signature 'IGTProjection'
plotIGTProjection(
  igtProjection,
  dimensions = 3,
  startDate = min(igtProjection@dataTemporalMap@dates),
  endDate = max(igtProjection@dataTemporalMap@dates),
  colorPalette = "Spectral",
  trajectory = FALSE
)
```

Arguments

`igtProjection`	of class `IGTProjection`
`dimensions`	number of dimensions of the plot, 2 or 3 (3 by default)

startDate	a Date object indicating the first date to be displayed in the IGT plot. By default the first date of the IGTProjection object.
endDate	a Date object indicating the last date to be displayed in the IGT plot By default the last date of the IGTProjection object.
colorPalette	color palette to be used. The default "Spectral" palette shows a color temperature scheme from blue, through yellow, to red (see "Spectral" palette in RColorBrewer package). The four remaining options are better suited for those with colorblindness, including "Viridis", "Magma", and their reversed versions "Viridis-reversed" and "Magma-reversed" (see "Viridis" and "Magma" palettes in the Viridis package).
trajectory	whether to show an estimated trajectory of the information evolution over time. By default FALSE.

Details

Note that since the projection is based on multidimensional scaling, a 2 dimensional projection entails a loss of information compared to a 3 dimensional projection. E.g., periodic variability components such as seasonal effect can be hindered by an abrupt change or a general trend.

Value

A plot object based on the plotly package.

Examples

```
load(system.file("extdata",
                 "variabilityDemoNHDSdiagcode1-phewascode.RData",
                  package="EHRtemporalVariability"))

p <- plotIGTProjection( igtProjection   =  igtProjs[[1]],
                        colorPalette    = "Spectral",
                        dimensions      = 2)
p

## Not run:

# For additional and larger examples download the following .Rdata file:

gitHubUrl  <- 'http://github.com/'
gitHubPath <- 'hms-dbmi/EHRtemporalVariability-DataExamples/'
gitHubFile <- 'raw/master/variabilityDemoNHDS.RData'
inputFile  <-  paste0(gitHubUrl, gitHubPath, gitHubFile)

load(url(inputFile))
plotIGTProjection(igtProjs$`diagcode1-phewascode`, dimensions = 3)

## End(Not run)
```

`trimDataTemporalMap` *Trims a* `DataTemporalMap`

Description

Trims a `DataTemporalMap` object between an start and end date. If one is not specified it takes as default the first/last chronological date in the input `DataTemporalMap`.

Usage

```
trimDataTemporalMap(
  dataTemporalMap,
  startDate = min(dataTemporalMap@dates),
  endDate = max(dataTemporalMap@dates)
)

## S4 method for signature 'DataTemporalMap'
trimDataTemporalMap(
  dataTemporalMap,
  startDate = min(dataTemporalMap@dates),
  endDate = max(dataTemporalMap@dates)
)
```

Arguments

`dataTemporalMap`	of class `DataTemporalMap`.
`startDate`	`Date` indicating the start date to trim from.
`endDate`	`Date` indicating the end date to trim to.

Value

A `DataTemporalMap` object between the specified dates.

Examples

```
load(system.file("extdata",
                 "variabilityDemoNHDSdiagcode1-phewascode.RData",
                  package="EHRtemporalVariability"))

probMapTrimmed <- trimDataTemporalMap(
                        dataTemporalMap = probMaps[[1]],
                        startDate       = "2005-01-01",
                        endDate         = "2008-12-01"
)
```

Index

DataTemporalMap
(DataTemporalMap-class), 2
DataTemporalMap,DataTemporalMap-class
(DataTemporalMap-class), 2
DataTemporalMap-class, 2

estimateDataTemporalMap, 3
estimateIGTProjection, 5
estimateIGTProjection,DataTemporalMap-method
(estimateIGTProjection), 5
estimateIGTProjection,IGTProjection-method
(estimateIGTProjection), 5
estimateIGTTrajectory, 7

formatDate, 7

icd9toPheWAS, 8
IGTProjection (IGTProjection-class), 9
IGTProjection,IGTProjection-class
(IGTProjection-class), 9
IGTProjection-class, 9

plotDataTemporalMap, 10
plotDataTemporalMap,DataTemporalMap-method
(plotDataTemporalMap), 10
plotIGTProjection, 12
plotIGTProjection,IGTProjection-method
(plotIGTProjection), 12

trimDataTemporalMap, 14
trimDataTemporalMap,DataTemporalMap-method
(trimDataTemporalMap), 14