

Package ‘EHRtemporalVariability’

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Type Package

Title Delineating Temporal Dataset Shifts in Electronic Health Records

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Description The 'EHRtemporalVariability' package contains 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. Dataset shifts can be explored and identified 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.

Depends R (>= 3.3.0), dplyr

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LazyData true

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

Suggests knitr, rmarkdown, devtools, BiocStyle

VignetteBuilder knitr

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URL <http://github.com/hms-dbmi/EHRtemporalVariability>

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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(system.file("extdata",
                               "nhdsSubset.csv",
                               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

<code>data</code>	a <code>data.frame</code> containing as many rows as individuals, and as many columns as the analysis variables plus the individual acquisition date.
<code>dateColumnName</code>	a string indicating the name of the column in <code>data</code> containing the analysis date variable.
<code>period</code>	the period at which to batch data for the analysis from "week", "month" and "year", with "month" as default.
<code>startDate</code>	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).
<code>endDate</code>	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).
<code>supports</code>	a List of objects containing the support of the data distributions for each variable, in classes <code>numeric</code> , <code>integer</code> , <code>character</code> , or <code>factor</code> (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.
<code>numericVariablesBins</code>	the number of bins at which to define the frequency/density histogram for numerical variables when their support is not provided, 100 as default.
<code>numericSmoothing</code>	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 <code>?density</code> for further details.
<code>dateGapsSmoothing</code>	a logical value indicating whether a linear smoothing is applied to those time batches without data, by default gaps are filled with NAs.
<code>verbose</code>	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(system.file("extdata",
                                "nhdsSubset.csv",
                                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)
```

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

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).

Value

An IGTProjection object containing the projected coordinates of each temporal batch in the embedded non-parametric Statistical Manifold

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)
```

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(system.file("extdata",
                                "nhdsSubset.csv",
                                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

<code>data</code>	A data.frame object with at least one column of ICD9-CM codes that one to be transformed into a PheWAS code.
<code>icd9ColumnName</code>	The name of the column containing the ICD9-CM.
<code>missingValues</code>	The value used to determine missing values in the data.frame.
<code>phecodeDescription</code>	By default FALSE. Change it to TRUE to map to the PheWAS code description instead to the PheWAS numeric code.
<code>statistics</code>	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.
<code>replaceColumn</code>	By default TRUE. Change it to FALSE in order to create a new column with the PheWAS code maintaining the ICD9-CM code.
<code>verbose</code>	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(system.file("extdata",
                                "nhdsSubset.csv",
                                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",
                              statistics   = TRUE
                              )
```

`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")
```

```
## 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")
```

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).

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

## 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). *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")

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

```

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).

Details

Note that since the projection is based on Classical Multi Dimensional 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"  
)
```

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