Package 'LPStimeSeries'

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Title Learned Pattern Similarity and Representation for Time Series

Author Learned Pattern Similarity (LPS) for time series by Mustafa Gokce Baydogan,Ensemble of regression trees by Andy Liaw and Matthew Wiener.

Depends R (>= 2.5.0), stats

Suggests RColorBrewer

Maintainer Mustafa Gokce Baydogan <baydoganmustafa@gmail.com>

Description Learned Pattern Similarity (LPS) for time series. This package is based on the 'randomForest' package by Andy Liaw. LPS aims at finding time series patterns to compute the similarity.

License GPL (>= 2)

URL http://www.mustafabaydogan.com/learned-pattern-similarity-lps.html

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`computeSimilarity` *Compute similarity between time series based on learned patterns*

Description

Compute similarity between time series. Raw time series can be provided together with `learnPattern` object so that the representation for the time series are generated internally and similarity is computed based on these representations. The other option is to provide the representations (instead of raw time series) and to compute the similarity without a need for `learnPattern` object.

Usage

```
computeSimilarity(object=NULL,testseries=NULL,refseries=NULL,
  maxdepth=NULL,which.tree=NULL,terminal=TRUE,testrepresentation,refrepresentation)
```

Arguments

`object`	an object of class `learnPattern`.
`refseries`	reference time series.
`testseries`	test time series.
`maxdepth`	maximum depth level to be used to generate representations for similarity computations.
`which.tree`	array of trees to be used for similarity computation.
`terminal`	`TRUE` if similarity is computed over the learned representations.
`testrepresentation`	learned representation for test time series.
`refrepresentation`	learned representation for reference time series.

Value

A similarity matrix of size “the number of test series“ by “the number of reference series“ is returned. Similarity between test series and reference series is defined as the number of mismatching patterns based on the representation generated by the trees. See LPS paper for details.

Note

Similarity matrix can also be computed over representations if it is generated using `predict.learnPattern`. This will probably take longer time compared to computing the similarity directly using the ensemble. However, if you are using LPS for retrieval purposes, bounding schemes (such as early abondon) can be used (requires further implementation) with the learned representations.

Author(s)

Mustafa Gokce Baydogan

References

Baydogan, M. G. (2013), "Learned Pattern Similarity", Homepage: http://www.mustafabaydogan.com/learned-pattern-similarity-lps.html.

See Also

learnPattern, predict.learnPattern

Examples

```
data(GunPoint)
set.seed(71)
## Learn patterns on GunPoint training series with default parameters
ensemble=learnPattern(GunPoint$trainseries)

## Find the similarity between test and training series
sim=computeSimilarity(ensemble,GunPoint$testseries,GunPoint$trainseries)

## Find similarity using representations,
## First generate representations
trainRep=predict(ensemble, GunPoint$trainseries, nodes=TRUE)
testRep=predict(ensemble, GunPoint$testseries, nodes=TRUE)

## Then compute the similarity (city-block distance),
## takes longer but we keep the representation
sim2=computeSimilarity(testrepresentation=testRep,refrepresentation=trainRep)

## Find the similarity based on first 100 trees
sim=computeSimilarity(ensemble,GunPoint$testseries,GunPoint$trainseries,which.tree=c(1:100))
```

---

getTreeInfo *Extract a single tree from the ensemble.*

Description

This function extracts the structure of a tree from a learnPattern object.

Usage

```
getTreeInfo(object, which.tree=1)
```

Arguments

object	a learnPattern object.
which.tree	which tree to extract?

Value

is a list with the following components:

`segment.length`	the proportion of the time series length used for both predictors and targets.
`target`	starting time of the target segment.
`target.type`	type of the target segment; 1 if observed series, 2 if difference series.
`tree`	Tree structure matrix with seven columns and number of rows equal to total number of nodes in the tree.

The seven columns of the `tree` structure matrix are:

`left daughter`	the row where the left daughter node is; 0 if the node is terminal
`right daughter`	the row where the right daughter node is; 0 if the node is terminal
`split segment`	start time of the segment used to split the node
`split type`	type of the predictor segment used to split the node; 1 if observed series, 2 if the different series are used. 0 if the node is terminal
`split point`	where the best split is
`status`	is the node terminal (-1) or not (-3)
`depth`	the depth of the node
`prediction`	the prediction for the node

Note

For numerical predictors, data with values of the variable less than or equal to the splitting point go to the left daughter node.

Author(s)

Mustafa Gokce Baydogan

See Also

`learnPattern`

Examples

```
data(GunPoint)
set.seed(71)

## Learn patterns on GunPoint training series with 50 trees
ensemble=learnPattern(GunPoint$trainseries,ntree=50)
getTreeInfo(ensemble, 3)
```

GunPoint *The Gun-Point Data*

Description

This is the Gun-Point data from The UCR Time Series Database.

Usage

```
data(GunPoint)
```

Format

GunPoint is a list with one training time series dataset and one test time series dataset provided as separate matrices. There are 50 cases (rows) for training dataset with 150 variables (columns). Similarly there are 150 cases for test dataset with 150 variables. Variables are representing the observations over time. In other words, they are ordered so that a row is a univariate time series. Originally, this is a classification problem where there are two classes. Therefore, list stores the class information for both training and test time series. This information is stored in arrays of length 50 and 150 for training and test time series respectively (so each time series is associated with a class).

Description by Chotirat Ann Ratanamahatana and Eamonn Keogh in their publication "Everything you know about Dynamic Time Warping is Wrong" is as follows:

"...This dataset comes from the video surveillance domain. The dataset has two classes, each containing 100 instances. All instances were created using one female actor and one male actor in a single session. The two classes are: Gun-Draw: The actors have their hands by their sides. They draw a replicate gun from a hip-mounted holster, point it at a target for approximately one second, then return the gun to the holster, and their hands to their sides. Point: The actors have their gun by their sides. They point with their index fingers to a target for approximately one second, and then return their hands to their sides. For both classes, we tracked the centroid of the actor's right hands in both X- and Y-axes, which appear to be highly correlated; therefore, in this experiment, we only consider the X-axis for simplicity..."

Author(s)

Mustafa Gokce Baydogan

Source

The original data is at http://www.cs.ucr.edu/~eamonn/time_series_data/.

References

Ratanamahatana, C. A. and Keogh. E. (2004). Everything you know about Dynamic Time Warping is Wrong. In proceedings of SIAM International Conference on Data Mining (SDM05), pp.506-510 Newport Beach, CA, April 21-23

See Also

learnPattern, computeSimilarity

Examples

```
data(GunPoint)
set.seed(71)

## Learn patterns on GunPoint training series with default parameters
ensemble=learnPattern(GunPoint$trainseries)
print(ensemble)

## Find the similarity between test and training series based on the learned model
similarity=computeSimilarity(ensemble,GunPoint$testseries,GunPoint$trainseries)

## Find the index of 1 nearest neighbor (1NN) training series for each test series
NearestNeighbor=apply(similarity,1,which.min)

## Predicted class for each test series
predicted=GunPoint$trainclass[NearestNeighbor]
print(predicted)
```

---

learnPattern *Learn Patterns for Time Series Representation and Similarity*

Description

learnPattern implements ensemble of regression trees (based on Breiman and Cutler's original Fortran code) to learn patterns for time series representation.

Usage

```
## Default S3 method:
learnPattern(x,
   segment.factor=c(0.05,0.95),
   random.seg=TRUE, target.diff=TRUE, segment.diff=TRUE,
   random.split=0,
   ntree=200,
   mtry=1,
   replace=FALSE,
   sampsize=if (replace) ceiling(0.632*nrow(x)) else nrow(x),
   maxdepth=6,
   nodesize=5,
   do.trace=FALSE,
   keep.forest=TRUE,
   oob.pred=FALSE,
   keep.errors=FALSE,
   keep.inbag=FALSE, ...)
```

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

Arguments

x	time series database as a matrix in UCR format. Rows are univariate time series, columns are observations (for the print method, a learnPattern object).
segment.factor	The proportion of the time series length to be used for both predictors and targets, if random.seg is TRUE (default), minimum and maximum factor should be provided as array of length two.
random.seg	TRUE if segment length is random between thresholds defined by segment.factor
target.diff	Can target segment be a difference feature?
segment.diff	Can predictor segments be difference feature?
random.split	Type of the split. If set to zero (0), splits are generated based on decrease in SSE in target segment Setting of one (1) generates the split value randomly between max and min values. Setting of two (2) generates a kd-tree type of split (i.e. median of the values at each node is chosen as the split).
ntree	Number of trees to grow. Larger number of trees are preferred if there is no concern regarding the computation time.
mtry	Number of predictor segments randomly sampled as candidates at each split. Note that it is preset to 1 for now.
replace	Should bagging of time series be done with replacement? All training time series are used if FALSE (default).
sampsize	Size(s) of sample to draw with replacement if replace is set to TRUE
maxdepth	The maximum depth of the trees in the ensemble.
nodesize	Minimum size of terminal nodes. Setting this number larger causes smaller trees to be grown (and thus take less time).
do.trace	If set to TRUE, give a more verbose output as learnPattern is run. If set to some integer, then running output is printed for every do.trace trees.
keep.forest	If set to FALSE, the forest will not be retained in the output object.
oob.pred	if replace is set to TRUE, predictions for the time series observations are returned.
keep.errors	If set to TRUE, the mean square error (MSE) of target prediction over target segments is evaluated for each tree. If oob.pred=TRUE, this information is evaluated on "out-of-bag" samples at each tree.
keep.inbag	Should an n by ntree matrix be returned that keeps track of which samples are "in-bag" in which trees
...	optional parameters to be passed to the low level function learnPattern.

Value

An object of class learnPattern, which is a list with the following components:

call	the original call to learnPattern.
type	regression

segment.factor	the proportion of the time series length to be used for both predictors and targets.
segment.length	used segment length settings by the trees of ensemble
nobs	number of observations in a segment
ntree	number of trees grown
maxdepth	maximum depth level for each tree
mtry	number of predictor segments sampled for spliting at each node.
target	starting time of the target segment for each tree.
target.type	type of the target segment; 1 if observed series, 2 if difference series.
forest	a list that contains the entire forest; NULL if keep.forest=FALSE.
oobprediction	predicted observations based on "out-of-bag" time series are returned if oob.pred=TRUE
ooberrors	Mean square error (MSE) over the trees evaluated using the predicted observations on "out-of-bag" time series is returned if oob.pred=TRUE.
inbag	n by ntree matrix be returned that keeps track of which samples are "in-bag" in which trees if keep.inbag=TRUE
errors	Mean square error (MSE) of target prediction over target segments for each tree. If oob.pred=TRUE, Mean square error (MSE) is reported based on "out-of-bag" samples at each tree.

Note

OOB predictions may have missing values (i.e. NA) if time series is not left out-of-bag during computations. Even, it is left out-of-bag, there is a potential of some observations (i.e. time frames) not being selected as the target. In such cases, there will no OOB predictions.

Author(s)

Mustafa Gokce Baydogan <baydoganmustafa@gmail.com>, based on original Fortran code by Leo Breiman and Adele Cutler, R port by Andy Liaw and Matthew Wiener.

References

Baydogan, M. G. (2013), "Learned Pattern Similarity", Homepage: http://www.mustafabaydogan.com/learned-pattern-similarity-lps.html.

Breiman, L. (2001), *Random Forests*, Machine Learning 45(1), 5-32.

See Also

predict.learnPattern, computeSimilarity, tunelearnPattern

Examples

```
data(GunPoint)
set.seed(71)

## Learn patterns on GunPoint training series with default parameters
ensemble=learnPattern(GunPoint$trainseries)
```

```
print(ensemble)

## Find the similarity between test and training series based on the learned model
similarity=computeSimilarity(ensemble,GunPoint$testseries,GunPoint$trainseries)

## Find the index of 1 nearest neighbor (1NN) training series for each test series
NearestNeighbor=apply(similarity,1,which.min)

## Predicted class for each test series
predicted=GunPoint$trainclass[NearestNeighbor]

## Compute the percentage of accurate predictions
accuracy=sum(predicted==GunPoint$testclass)/nrow(GunPoint$testseries)
print(100*accuracy)

## Learn patterns randomly on GunPoint training series with default parameters
ensemble=learnPattern(GunPoint$trainseries, random.split=1)

## Find the similarity between test and training series and classify test series
similarity=computeSimilarity(ensemble,GunPoint$testseries,GunPoint$trainseries)
NearestNeighbor=apply(similarity,1,which.min)
predicted=GunPoint$trainclass[NearestNeighbor]
accuracy=sum(predicted==GunPoint$testclass)/nrow(GunPoint$testseries)
print(100*accuracy)

## Learn patterns by training each tree on a random subsample
## and classify test time series
ensemble=learnPattern(GunPoint$trainseries,replace=TRUE)
similarity=computeSimilarity(ensemble,GunPoint$testseries,GunPoint$trainseries)
NearestNeighbor=apply(similarity,1,which.min)
predicted=GunPoint$trainclass[NearestNeighbor]
print(predicted)

## Learn patterns and do predictions on OOB time series
ensemble=learnPattern(GunPoint$trainseries,replace=TRUE,target.diff=FALSE,oob.pred=TRUE)
## Plot first series and its OOB approximation
plot(GunPoint$trainseries[1,],type='l',lty=1,xlab='Time',ylab='Observation',lwd=2)
points(c(1:ncol(GunPoint$trainseries)),ensemble$oobpredictions[1,],type='l',col=2,lty=2,lwd=2)
legend('topleft',c('Original series','Approximation'),col=c(1,2),lty=c(1,2),lwd=2)
```

LPSNews *Show the NEWS file*

Description

Show the NEWS file of the LPStimeSeries package.

Usage

```
LPSNews()
```

Value

None.

`plot.learnPattern` *Plot method for learnPattern objects*

Description

Plot the MSE of a learnPattern object over trees based on out-of-bag predictions

Usage

```
## S3 method for class 'learnPattern'
plot(x, type="l", main=deparse(substitute(x)), ...)
```

Arguments

`x`	an object of class `learnPattern`.
`type`	type of plot.
`main`	main title of the plot.
`...`	other graphical parameters.

Value

Invisibly, MSE of the `learnPattern` object.

Note

This function does not work for `learnPattern` if `oob.predict=FALSE` during training.

Author(s)

Mustafa Gokce Baydogan

See Also

`learnPattern`

Examples

```
data(GunPoint)
ensemble=learnPattern(GunPoint$trainseries,oob.pred=TRUE,replace=TRUE)
plot(ensemble)
```

plotMDS *Multi-dimensional Scaling Plot of Learned Pattern Similarity*

Description

Plot the scaling coordinates of the Learned Pattern Similarity.

Usage

```
plotMDS(object, newdata, classinfo, k=2, palette=NULL, pch=20, ...)
```

Arguments

object	an object of class learnPattern, as that created by the function learnPattern.
newdata	a data frame or matrix containing the data for similarity computation.
classinfo	labels for the time series for color-coding.
k	number of dimensions for the scaling coordinates.
palette	colors to use to distinguish the classes; length must be the equal to the number of levels.
pch	plotting symbols to use.
...	other graphical parameters.

Value

The output of cmdscale on scaled Learned Pattern similarity is returned invisibly.

Note

If k > 2, pairs is used to produce the scatterplot matrix of the coordinates.

The entries of the similarity matrix is divided by the maximum possible similarity which is 2*sum(object$nobs)

Author(s)

Mustafa Gokce Baydogan

See Also

learnPattern

Examples

```
set.seed(1)
data(GunPoint)
## Learn patterns on GunPoint training series with default parameters
ensemble=learnPattern(GunPoint$trainseries)
plotMDS(ensemble, GunPoint$trainseries,GunPoint$trainclass)

## Using different symbols for the classes:
plotMDS(ensemble, GunPoint$trainseries,GunPoint$trainclass,
         palette=rep(1, 2), pch=as.numeric(GunPoint$trainclass))

## Learn patterns on GunPoint training series with random splits
ensemble=learnPattern(GunPoint$trainseries,random.split=1)
plotMDS(ensemble, GunPoint$trainseries,GunPoint$trainclass,main='Random Splits')
```

---

predict.learnPattern *predict method for* learnPattern *objects*

Description

Representation generation for test data using learnPattern.

Usage

```
## S3 method for class 'learnPattern'
predict(object, newdata, which.tree=NULL,
   nodes=TRUE, maxdepth=NULL, ...)
```

Arguments

object	an object of class learnPattern, as that created by the function learnPattern.
newdata	a data frame or matrix containing new data.
which.tree	NULL if the representation is needed to be generated over all trees of ensemble. Set to an integer value if the representation is required to be generated for one tree specified by the value set.
nodes	TRUE generates the representation based on the trees. . FALSE generates a real-valued prediction for each time point.
maxdepth	The maximum depth level to generate the representation
...	not used currently.

Value

Returns the learned pattern representation for the time series in the dataset if nodes is set TRUE. Basically, it is the count of observed patterns at each terminal node. Otherwise predicted values for each time series in newdata are returned.

Author(s)

Mustafa Gokce Baydogan

References

Baydogan, M. G. (2013), "Learned Pattern Similarity", Homepage: http://www.mustafabaydogan.com/learned-pattern-similarity-lps.html.

Breiman, L. (2001), *Random Forests*, Machine Learning 45(1), 5-32.

See Also

learnPattern

Examples

```
data(GunPoint)
set.seed(71)
## Learn patterns on GunPoint training series with default parameters
ensemble=learnPattern(GunPoint$trainseries)

## Find representations
trainRep=predict(ensemble, GunPoint$trainseries, nodes=TRUE)
testRep=predict(ensemble, GunPoint$testseries, nodes=TRUE)

## Check size of the representation for training data
print(dim(trainRep))

## Learn patterns on GunPoint training series (target cannot be difference series)
ensemble=learnPattern(GunPoint$trainseries,target.diff=FALSE)

## Predict observations for test time series
predicted=predict(ensemble,GunPoint$testseries,nodes=FALSE)

## Plot an example test time series
plot(GunPoint$testseries[5,],type='l',lty=1,xlab='Time',ylab='Observation',lwd=2)
points(c(1:ncol(GunPoint$testseries)),predicted$predictions[5,],type='l',col=2,lty=2,lwd=2)
legend('topleft',c('Original series','Approximation'),col=c(1,2),lty=c(1,2),lwd=2)
```

---

tunelearnPattern *Tune Parameters of LPS for Time Series Classification*

Description

tunelearnPattern implements parameter selection for LPS in time series classification problems. LPS requires the setting of segment length (if segment length is not random) and depth parameter. Given training time series and alternative parameter settings, the best set of parameters that minimizes the cross-validation error rate is returned.

Usage

```
tunelearnPattern(x, y, unlabeledx=NULL, nfolds=5,
   segmentlevels=c(0.25,0.5,0.75), random.split=0,
   mindepth=4, maxdepth=8, depthstep=2,
   ntreeTry=25, target.diff=TRUE, segment.diff=TRUE, ...)
```

Arguments

x	time series database as a matrix in UCR format. Rows are univariate time series, columns are observations (for the print method, a learnPattern object).
y	labels for the time series given by x
unlabeledx	unlabeled time series dataset. Introduced for future purposes as LPS can benefit from unlabeled data.
nfolds	number of cross-validation folds for parameter evaluation.
segmentlevels	alternative segment level settings to be evaluated. Settings are provided as an array.
random.split	Type of the split. If set to zero (0), splits are generated based on decrease in SSE in target segment Setting of one (1) generates the split value randomly between max and min values. Setting of two (2) generates a kd-tree type of split (i.e. median of the values at each node is chosen as the split).
mindepth	minimum depth level to be evaluated.
maxdepth	maximum depth level to be evaluated.
depthstep	step size to determine the depth levels between mindepth and maxdepth to be evaluated.
ntreeTry	number of trees to be train for each fold.
target.diff	Can target segment be a difference feature?
segment.diff	Can predictor segments be difference feature?
...	optional parameters to be passed to the low level function tunelearnPattern.

Value

A list with the following components:

params	evaluated parameter combinations as a matrix where rows are parameter combinations and columns represent the settings. First and seconds columns are the evaluated segment length level and depth respectively.
errors	cross-validation error rate for each parameter combinations
best.error	the minimum cross-validation error rate obtained.
best.seg	the segment length level that provides the minimum cross-validation error.
best.depth	the depth level that provides the minimum cross-validation error.
random.split	split type used for learning patterns.

Author(s)

Mustafa Gokce Baydogan <baydoganmustafa@gmail.com>, based on original Fortran code by Leo Breiman and Adele Cutler, R port by Andy Liaw and Matthew Wiener.

References

Baydogan, M. G. (2013), "Learned Pattern Similarity", Homepage: http://www.mustafabaydogan.com/learned-pattern-similarity-lps.html.

Breiman, L. (2001), *Random Forests*, Machine Learning 45(1), 5-32.

See Also

learnPattern, computeSimilarity

Examples

```
data(GunPoint)
set.seed(71)

## Tune segment length level and depth on GunPoint training series
tuned=tunelearnPattern(GunPoint$trainseries,GunPoint$trainclass)
print(tuned$best.error)
print(tuned$best.seg)
print(tuned$best.depth)

## Use tuned parameters to learn patterns
ensemble=learnPattern(GunPoint$trainseries,segment.factor=tuned$best.seg,
  maxdepth=tuned$best.depth)

## Find the similarity between test and training series based on the learned model
similarity=computeSimilarity(ensemble,GunPoint$testseries,GunPoint$trainseries)

## Find the index of 1 nearest neighbor (1NN) training series for each test series
NearestNeighbor=apply(similarity,1,which.min)

## Predicted class for each test series
predicted=GunPoint$trainclass[NearestNeighbor]

## Compute the percentage of accurate predictions
accuracy=sum(predicted==GunPoint$testclass)/nrow(GunPoint$testseries)
print(100*accuracy)
```

---

visualizePattern *Plot of the patterns learned by the ensemble of the regression trees*

Description

visualizePattern visualizes the patterns implied by the terminal nodes of the trees from learnPattern object.

Usage

```
visualizePattern(object, x, which.terminal, orient=c(2,2))
```

Arguments

object	an object of class learnPattern, as that created by the function learnPattern.
x	a data frame or matrix containing the data for pattern visualization.
which.terminal	id of the terminal node determining the decision rules to be used for identifying patterns
orient	orientation of the plot (determines the grid structure and how many patterns to be visualized).

Value

A list with the following components are returned invisibly.

predictor	predictor segments residing in the which.terminal.
target	target segments implied by the which.terminal.
tree	the tree id corresponding to the which.terminal.
terminal	the id of the terminal node for the tree.

Note

Patterns are visualized for the time series for which the frequency of the observations in the pattern is the largest. If more than one plot is requested through the setting of orient, the patterns are plotted for the time series based on the descending order of the frequency.

Currently, patterns are visualized based on the first predictor segment (sampled at the root node). This visualization can be done based on the predictor segment sampled at each level of the tree.

predictor and target are of size x where the patterns are numerical values and the rest of the entries are NAs.

Author(s)

Mustafa Gokce Baydogan

See Also

learnPattern,predict.learnPattern

Examples

```
set.seed(71)
data(GunPoint)
## Learn patterns on GunPoint training series with default parameters
ensemble=learnPattern(GunPoint$trainseries)

## Find representations
trainRep=predict(ensemble, GunPoint$trainseries, nodes=TRUE)
```

```
## Find the average frequency over the terminal nodes
avgFreq=apply(trainRep,2,mean)

## Find the terminal node that has the maximum average and visualize
termid=which.max(avgFreq)
visualizePattern(ensemble,GunPoint$trainseries,termid,c(2,1))
```

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