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Title Volume under the ROC Surface for Multi-Class ROC Analysis

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Description Calculates the volume under the ROC surface and its (co)variance for ordered multi-class ROC analysis as well as certain bivariate ordinal measures of association.

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Contents

VUROCS-package *Volume under the ROC Surface for Multi-Class ROC Analysis*

Description

Calculates the volume under the ROC surface and its (co)variance for ordered multi-class ROC analysis as well as certain bivariate ordinal measures of association.

Details

The package VUROCS provides three core functions to determine the volume under the ROC surface (VUS) as well as the variance and covariance of the VUS. The implementation is generally based on the algorithms presented in Waegeman, De Baets and Boullart (2008).

- `VUS(y,fx)` calculates the VUS for a vector of realizations `y` and a vector of predictions `fx`.
- `VUSvar(y,fx)` calculates the variance of VUS for a vector of realizations `y` and a vector of predictions `fx`.
- `VUScov(y,fx1,fx2)` calculates the covariance of the two VUS implied by the predictions `fx1` and `fx2` for a vector of realizations `y`.

In addition to these three core functions, the package also provides an implementation of the cumulative LGD accuracy ratio (CLAR) suggested by Ozdemir and Miu (2009) specially for the purpose of assessing the discriminatory power of Loss Given Default (LGD) credit risk models. The CLAR as well as an adjusted version are computed by the functions `clar` and `clarAdj`. Moreover, the package provides time-efficient implementations of Somers' D , Kruskall's Gamma, Kendall's Tau_b and Kendall's Tau_c in the functions `SomersD`, `Kruskal_Gamma`, `Kendall_taub` and `Kendall_tauc`. These functions also compute asymptotic standard errors defined by Brown and Benedetti (1977) and Goktas and Oznur (2011).

Author(s)

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References

Brown, M.B., Benedetti, J.K., 1977. Sampling Behavior of Tests for Correlation in Two-Way Contingency Tables. Journal of the American Statistical Association 72(358), 309-315

Goktas, A., Oznur, I., 2011. A Comparison of the Most Commonly Used Measures of Association for Doubly Ordered Square Contingency Tables via Simulation. Metodoloski zvezki 8 (1), 17-37

Ozdemir, B., Miu, P., 2009. Basel II Implementation: A Guide to Developing and Validating a Compliant, Internal Risk Rating System. McGraw-Hill, USA.

Waegeman W., De Baets B., Boullart L., 2008. On the scalability of ordered multi-class ROC analysis. Computational Statistics & Data Analysis 52, 3371-3388.

Examples

```
y  <- rep(1:5,each=3)
fx <- c(3,3,3,rep(2:5,each=3))

VUS(y,fx)
clar(y,fx)
clarAdj(y,fx)
SomersD(y,fx)
Kruskal_Gamma(y,fx)
Kendall_taub(y,fx)
Kendall_tauc(y,fx)

VUSvar(rep(1:5,each=3),c(1,2,3,rep(2:5,each=3)))
VUScov(c(1,2,1,3,2,3),c(1,2,3,4,5,6),c(1,3,2,4,6,5))
```

`clar` *Cumulative LGD Accuracy Ratio*

Description

Calculates for a vector of realized categories `y` and a vector of predicted categories `hx` the cumulative LGD accuarcy ratio (CLAR) according to Ozdemir and Miu 2009.

Usage

```
clar(y, hx)
```

Arguments

`y`	a vector of realized values.
`hx`	a vector of predicted values.

Value

The function returns the CLAR for a vector of realized categories `y` and a vector of predicted categories `hx`.

References

Ozdemir, B., Miu, P., 2009. Basel II Implementation. A Guide to Developing and Validating a Compliant Internal Risk Rating System. McGraw-Hill, USA.

Examples

```
clar(rep(1:5,each=3),c(3,3,3,rep(2:5,each=3)))
```

clarAdj — *Adjusted Cumulative LGD Accuracy Ratio*

Description

Calculates for a vector of realized categories y and a vector of predicted categories hx the cumulative LGD accuarcy ratio (CLAR) according to Ozdemir and Miu (2009) and adjusts it such that the measure has a value of zero if the two ordinal rankings are in reverse order.

Usage

```
clarAdj(y, hx)
```

Arguments

y	a vector of realized categories.
hx	a vector of predicted categories.

Value

The function returns the adjusted CLAR for a vector of realized categories y and a vector of predicted categories hx.

References

Ozdemir, B., Miu, P., 2009. Basel II Implementation. A Guide to Developing and Validating a Compliant Internal Risk Rating System. McGraw-Hill, USA.

Examples

```
clarAdj(rep(1:5,each=3),c(3,3,3,rep(2:5,each=3)))
```

Kendall_taub — *Kendall's Tau_b and its asymptotic standard errors*

Description

Computes Kendall's Tau_b on a given cartesian product Y x f(X), where Y consists of the components of y and f(X) consists of the components of fx. Furthermore, the asymptotic standard error as well as the modified asymptotic standard error to test the null hypothesis that the measure is zero are provided as defined in Brown and Benedetti (1977).

Usage

```
Kendall_taub(y, fx)
```

Arguments

`y`	a vector of realized categories.
`fx`	a vector of predicted values of the ranking function f.

Value

A list of length three is returned, containing the following components:

`val`	Kendall's Tau_b
`ASE`	the asymptotic standard error of Kendall's Tau_b
`ASE0`	the modified asymptotic error of Kendall's Tau_b under the null hypothesis

References

Brown, M.B., Benedetti, J.K., 1977. Sampling Behavior of Tests for Correlation in Two-Way Contingency Tables. Journal of the American Statistical Association 72(358), 309-315

Examples

```
Kendall_taub(rep(1:5,each=3),c(3,3,3,rep(2:5,each=3)))
```

`Kendall_tauc` *Kendall's Tau_c and its asymptotic standard errors*

Description

Computes Kendall's Tau_c on a given cartesian product Y x f(X), where Y consists of the components of `y` and f(X) consists of the components of `fx`. Furthermore, the asymptotic standard error as well as the modified asymptotic standard error to test the null hypothesis that the measure is zero are provided as defined in Brown and Benedetti (1977).

Usage

```
Kendall_tauc(y, fx)
```

Arguments

`y`	a vector of realized categories.
`fx`	a vector of predicted values of the ranking function f.

Value

A list of length three is returned, containing the following components:

`val`	Kendall's Tau_c
`ASE`	the asymptotic standard error of Kendall's Tau_c
`ASE0`	the modified asymptotic error of Kendall's Tau_c under the null hypothesis

References

Brown, M.B., Benedetti, J.K., 1977. Sampling Behavior of Tests for Correlation in Two-Way Contingency Tables. Journal of the American Statistical Association 72(358), 309-315

Examples

```
Kendall_tauc(rep(1:5,each=3),c(3,3,3,rep(2:5,each=3)))
```

Kruskal_Gamma — *Kruskal's Gamma and its asymptotic standard errors*

Description

Computes Kruskal's Gamma on a given cartesian product Y x f(X), where Y consists of the components of `y` and f(X) consists of the components of `fx`. Furthermore, the asymptotic standard error as well as the modified asymptotic standard error to test the null hypothesis that the measure is zero are provided as defined in Brown and Benedetti (1977).

Usage

```
Kruskal_Gamma(y, fx)
```

Arguments

`y`	a vector of realized categories.
`fx`	a vector of predicted values of the ranking function f.

Value

A list of length three is returned, containing the following components:

`val`	Kruskal's Gamma
`ASE`	the asymptotic standard error of Kruskal's Gamma
`ASE0`	the modified asymptotic error of Kruskal's Gamma under the null hypothesis

References

Brown, M.B., Benedetti, J.K., 1977. Sampling Behavior of Tests for Correlation in Two-Way Contingency Tables. Journal of the American Statistical Association 72(358), 309-315

Examples

```
Kruskal_Gamma(rep(1:5,each=3),c(3,3,3,rep(2:5,each=3)))
```

SomersD — *Somers' D and its asymptotic standard errors*

Description

Computes Somers' D on a given cartesian product Y x f(X), where Y consists of the components of `y` and f(X) consists of the components of `fx`. Furthermore, the asymptotic standard error as well as the modified asymptotic standard error to test the null hypothesis that the measure is zero are provided as defined in Goktas and Oznur (2011).

Usage

```
SomersD(y, fx)
```

Arguments

`y`	a vector of realized categories.
`fx`	a vector of predicted values of the ranking function f.

Value

A list of length three is returned, containing the following components:

`val`	Somers' D
`ASE`	the asymptotic standard error of Somers' D
`ASE0`	the modified asymptotic error of Somers' D under the null hypothesis.

References

Goktas, A., Oznur, I., 2011. A Comparison of the Most Commonly Used Measures of Association for Doubly Ordered Square Contingency Tables via Simulation. Metodoloski zvezki 8 (1), 17-37

Examples

```
SomersD(rep(1:5,each=3),c(3,3,3,rep(2:5,each=3)))
```

`VUS` *Volume under the ROC surface*

Description

This function computes the volume under the ROC surface (VUS) for a vector of realisations `y` (i.e. realised categories) and a vector of predictions `fx` (i.e. values of the a ranking function f) for the purpose of assessing the discrimiatory power in a multi-class classification problem. This is achieved by counting the number of r-tuples that are correctly ranked by the ranking function f. Thereby, r is the number of classes of the response variable `y`.

Usage

```
VUS(y, fx)
```

Arguments

`y`	a vector of realized categories.
`fx`	a vector of predicted values of the ranking function f.

Value

The implemented algorithm is based on Waegeman, De Baets and Boullart (2008). A list of length two is returned, containing the following components:

`val`	volume under the ROC surface
`count`	counts the number of observations falling into each category

References

Waegeman W., De Baets B., Boullart L., 2008. On the scalability of ordered multi-class ROC analysis. Computational Statistics & Data Analysis 52, 3371-3388.

Examples

```
VUS(rep(1:5,each=3),c(3,3,3,rep(2:5,each=3)))
```

VUScov *Covariance of two volumes under the ROC surface*

Description

Computes the covariance of the two volumes under the ROC surface (VUS) implied by two predictions `fx1` and `fx2` (i.e. values of two ranking functions f1 and f2) for a vector of realisations `y` (i.e. realised categories) in a multi-class classification problem.

Usage

```
VUScov(y, fx1, fx2, ncores = 1, clusterType = "SOCK")
```

Arguments

`y`	a vector of realized categories.
`fx1`	a vector of predicted values of the ranking function f1.
`fx2`	a vector of predicted values of the ranking function f2.
`ncores`	number of cores to be used for parallelized computations. Its default value is 1.
`clusterType`	type of cluster to be initialized in case more than one core is used for calculations. Its default value is "SOCK". For details regarding the different types to be used, see `makeCluster`.

Value

The implemented algorithm is based on Waegeman, De Baets and Boullart (2008). A list of length three is returned, containing the following components:

`cov`	covariance of the two volumes under the ROC surface implied by f1 and f2
`val_f1`	volume under the ROC surface implied by f1
`val_f2`	volume under the ROC surface implied by f2

References

Waegeman W., De Baets B., Boullart L., 2008. On the scalability of ordered multi-class ROC analysis. Computational Statistics & Data Analysis 52, 3371-3388.

Examples

```
VUScov(c(1,2,1,3,2,3),c(1,2,3,4,5,6),c(1,3,2,4,6,5))
```

VUSvar *Variance of the volume under the ROC surface*

Description

Computes the volume under the ROC surface (VUS) and its variance for a vector of realisations y (i.e. realised categories) and a vector of predictions fx (i.e. values of the a ranking function f) for the purpose of assessing the discrimiatory power in a multi-class classification problem.

Usage

```
VUSvar(y, fx, ncores = 1, clusterType = "SOCK")
```

Arguments

y	a vector of realized categories.
fx	a vector of predicted values of the ranking function f.
ncores	number of cores to be used for parallelized computations. The default value is 1.
clusterType	type of cluster to be initialized in case more than one core is used for calculations. The default values is "SOCK". For details regarding the different types to be used, see makeCluster.

Value

The implemented algorithm is based on Waegeman, De Baets and Boullart (2008). A list of length two is returned, containing the following components:

var	variance of the volume under the ROC surface
val	volume under the ROC surface

References

Waegeman W., De Baets B., Boullart L., 2008. On the scalability of ordered multi-class ROC analysis. Computational Statistics & Data Analysis 52, 3371-3388.

Examples

```
VUSvar(rep(1:5,each=3),c(1,2,3,rep(2:5,each=3)))
```

Index