Package 'Copula.Markov'

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Type Package

Title Copula-Based Estimation and Statistical Process Control for Serially Correlated Time Series

Version 2.4

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Description Estimation and statistical process control are performed under copula-based time-series models.
Available are statistical methods in Long and Emura (2014 JCSA),
Emura et al. (2017 Commun Stat-Simul) <DOI:10.1080/03610918.2015.1073303>,
Huang and Emura(2019, in revision) and Huang, Chen and Emura (2019-, in revision).

License GPL-2

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R topics documented:

`Copula.Markov-package` *Copula-Based Estimation and Statistical Process Control for Serially Correlated Time Series*

Description

Copulas are applied to model a Markov dependence for serially correlated time series. The Clayton and Joe copulas are available to specify the dependence structure. The normal and binomial distributions are available for the marginal model. Maximum likelihood estimation is implmented for estimating parameters, and a Shewhart control chart is drawn for performing statistical process control.

Details

Package:	Copula.Markov
Type:	Package
Version:	2.4
Date:	2019-03-24
License:	GPL-2

Author(s)

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References

Chen W (2018) Copula-based Markov chain model with binomial data, NCU Library

Huang XW, Chen W, Emura T (2019-), A control chart using a copula-based Markov chain for attribute data, revision

Emura T, Long TH, Sun LH (2017), R routines for performing estimation and statistical process control under copula-based time series models, Communications in Statistics - Simulation and Computation, 46 (4): 3067-87

Long TH and Emura T (2014), A control chart using copula-based Markov chain models, Journal of the Chinese Statistical Association 52 (No.4): 466-96

Huang XW, Emura T (2019-), Model diagnostic procedures for copula-based Markov chain models for statistical process control, in revision

`Clayton.Markov.DATA` *Generating Time Series Data Under a Copula-Based Markov Chain Model with the Clayton Copula*

Description

Time-series datasets are generated under a copula-based Markov chain model with the Clayton copula.

Usage

```
Clayton.Markov.DATA(n, mu, sigma, alpha)
```

Arguments

`n`	sample size
`mu`	mean
`sigma`	standard deviation
`alpha`	association parameter

Details

-1<alpha<0 for negative association; alpha>0 for positive association

Value

time series data

Author(s)

Takeshi Emura

References

Emura T, Long TH, Sun LH (2017), R routines for performing estimation and statistical process control under copula-based time series models, Communications in Statistics - Simulation and Computation, 46 (4): 3067-87

Long TH and Emura T (2014), A control chart using copula-based Markov chain models, Journal of the Chinese Statistical Association 52 (No.4): 466-96

Examples

```
set.seed(1)
Y=Clayton.Markov.DATA(n=1000,mu=0,sigma=1,alpha=8)
Clayton.Markov.MLE(Y,plot=TRUE)
```

`Clayton.Markov.DATA.binom` *Generating Time Series Data Under a Copula-Based Markov Chain Model with the Clayton Copula and Binomial Margin.*

Description

Time-series datasets are generated under a copula-based Markov chain model with the Clayton copula and binomial margin.

Usage

```
Clayton.Markov.DATA.binom(n, size, prob, alpha)
```

Arguments

`n`	number of observations
`size`	number of binomial trials
`prob`	binomial probability; 0<p<1
`alpha`	association parameter

Details

-1<alpha<0 for negative association; alpha>0 for positive association

Value

time series data

Author(s)

Huang XW, Chen W, Emura T

References

Chen W (2018) Copula-based Markov chain model with binomial data, NCU Library

Huang XW, Chen W, Emura T (2019) A control chart using a copula-based Markov chain for attribute data, in revision.

Examples

```
size=50
prob=0.5
alpha=2
set.seed(1)
Y=Clayton.Markov.DATA.binom(n=500,size,prob,alpha)
### sample mean and SD ###
```

```
mean(Y)
sd(Y)
### true mean and SD ###
size*prob
sqrt(size*prob*(1-prob))
```

`Clayton.Markov.GOF` *Goodness-of-fit test*

Description

Perform a parametric bootstrap test.

Usage

```
Clayton.Markov.GOF(Y, k = 3, D = 1, B = 200,GOF.plot=FALSE)
```

Arguments

`Y`	vector of datasets
`k`	constant determining the length between LCL and UCL (k=3 corresponds to 3-sigma limit)
`D`	diameter for U(-D, D) used in randomized Newton-Raphson
`B`	the number of Bootstrap replications
`GOF.plot`	if TRUE, show the model diagnostic plots for B bootstrap replications

Value

`CM`	Cramer-von Mises test
`KS`	Kolmogorov-Smirnov test

Author(s)

Takeshi Emura

References

Emura T, Long TH, Sun LH (2017), R routines for performing estimation and statistical process control under copula-based time series models, Communications in Statistics - Simulation and Computation, 46 (4): 3067-87

Long TH and Emura T (2014), A control chart using copula-based Markov chain models, Journal of the Chinese Statistical Association 52 (No.4): 466-96

Huang XW, Emura T (2019-), Model diagnostic procedures for copula-based Markov chain models for statistical process control, in revision

Examples

```
set.seed(1)
Y=Clayton.Markov.DATA(n=1000,mu=0,sigma=1,alpha=2)
Clayton.Markov.GOF(Y,B=5,GOF.plot=TRUE)
```

`Clayton.Markov.GOF.binom` *Goodness-of-fit test*

Description

Perform a parametric bootstrap test.

Usage

```
Clayton.Markov.GOF.binom(Y, k = 3, size, B = 200,GOF.plot=FALSE)
```

Arguments

`Y`	vector of datasets
`k`	constant determining the length between LCL and UCL (k=3 corresponds to 3-sigma limit)
`size`	number of binomial trials
`B`	the number of Bootstrap replications
`GOF.plot`	if TRUE, show the model diagnostic plots for B bootstrap replications

Value

`CM`	Cramer-von Mises test
`KS`	Kolmogorov-Smirnov test

Author(s)

Huang XW, Emura T

References

Huang XW, Chen W, Emura T (2019) A control chart using a copula-based Markov chain for attribute data, in revision.

Examples

```
size=50
prob=0.5
alpha=2
set.seed(1)
Y=Clayton.Markov.DATA.binom(n=500,size,prob,alpha)
Clayton.Markov.GOF.binom(Y,size=size,B=5,k=3,GOF.plot=TRUE) ## B=5 to save time
```

`Clayton.Markov.MLE` *Maximum Likelihood Estimation and Statistical Process Control Under the Clayton Copula*

Description

The maximum likelihood estimates are produced and the Shewhart control chart is drawn with k-sigma control limits (e.g., 3-sigma). The dependence model follows the Clayton copula and the marginal (stationary) distribution follows the normal distribution.

Usage

```
Clayton.Markov.MLE(Y, k = 3, D = 1, plot = TRUE,GOF=FALSE)
```

Arguments

`Y`	vector of datasets
`k`	constant determining the length between LCL and UCL (k=3 corresponds to 3-sigma limit)
`D`	diameter for U(-D, D) used in randomized Newton-Raphson
`plot`	show the control chart if TRUE
`GOF`	show the model diagnostic plot if TRUE

Value

`estimates`	estimates
`out_of_control`	IDs for out-of-control points
`Gradient`	gradients (must be zero)
`Hessian`	Hessian matrix
`Mineigenvalue_Hessian`	Minimum eigenvalue for the Hessian matrix
`CM.test`	Cramer-von Mises test statistics
`KS.test`	Kolmogorov-Smirnov test statistics

Author(s)

Takeshi Emura

References

Emura T, Long TH, Sun LH (2017), R routines for performing estimation and statistical process control under copula-based time series models, Communications in Statistics - Simulation and Computation, 46 (4): 3067-87

Long TH and Emura T (2014), A control chart using copula-based Markov chain models, Journal of the Chinese Statistical Association 52 (No.4): 466-96

Examples

```
set.seed(1)
Y=Clayton.Markov.DATA(n=1000,mu=0,sigma=1,alpha=2)
Clayton.Markov.MLE(Y,plot=TRUE)
```

`Clayton.Markov.MLE.binom` *Maximum Likelihood Estimation and Statistical Process Control Under the Clayton Copula*

Description

The maximum likelihood estimates are produced and the Shewhart control chart is drawn with k-sigma control limits (e.g., 3-sigma). The dependence model follows the Clayton copula and the marginal (stationary) distribution follows the normal distribution.

Usage

```
Clayton.Markov.MLE.binom(Y, size, k = 3, method="nlm", plot = TRUE, GOF=FALSE)
```

Arguments

`Y`	vector of observations
`size`	numbe of binomial trials
`method`	nlm or Newton
`k`	constant determining the length between LCL and UCL (k=3 corresponds to 3-sigma limit)
`plot`	show the control chart if TRUE
`GOF`	show the model diagnostic plot if TRUE

Value

`p`	estimate, SE, and 95CI
`alpha`	estimate, SE, and 95CI
`out_of_control`	IDs for out-of-control points
`Gradient`	gradients (must be zero)
`Hessian`	Hessian matrix
`Mineigenvalue_Hessian`	Minimum eigenvalue for the Hessian matrix

Author(s)

Huang XW, Emura T

References

Chen W (2018) Copula-based Markov chain model with binomial data, NCU Library

Huang XW, Chen W, Emura T (2019) A control chart using a copula-based Markov chain for attribute data, in revision.

Examples

```
size=50
prob=0.5
alpha=2
set.seed(1)
Y=Clayton.Markov.DATA.binom(n=500,size,prob,alpha)
Clayton.Markov.MLE.binom(Y,size=size,k=3,plot=TRUE)
```

Clayton.Markov2.DATA *Generating Time Series Data Under a Copula-Based 2nd-order Markov Chain Model with the Clayton Copula*

Description

Time-series datasets are generated under a copula-based 2nd order Markov chain model with the Clayton copula.

Usage

```
Clayton.Markov2.DATA(n, mu, sigma, alpha)
```

Arguments

n	sample size
mu	mean
sigma	standard deviation
alpha	association parameter

Details

-1<alpha<0 for negative association; alpha>0 for positive association

Value

time series data

Author(s)

Xinwei Huang and Takeshi Emura

References

Huang XW, Emura T (2019-), Model diagnostic procedures for copula-based Markov chain models for statistical process control, in revision

Examples

```
Clayton.Markov2.DATA(n = 100, mu = 0, sigma = 1, alpha = 2)
```

`Clayton.Markov2.MLE` *Maximum Likelihood Estimation and Statistical Process Control Under the Clayton Copula with a 2nd order Markov chain.*

Description

The maximum likelihood estimates are produced and the Shewhart control chart is drawn with k-sigma control limits (e.g., 3-sigma). The dependence model follows the Clayton copula and the marginal (stationary) distribution follows the normal distribution.

Usage

```
Clayton.Markov2.MLE(Y, k = 3, D = 1, plot = TRUE, GOF=FALSE)
```

Arguments

`Y`	vector of datasets
`k`	constant determining the length between LCL and UCL (k=3 corresponds to 3-sigma limit)
`D`	diameter for U(-D, D) used in randomized Newton-Raphson
`plot`	show the control chart if TRUE
`GOF`	show the model diagnostic plot if TRUE

Value

`estimates`	estimates
`out_of_control`	IDs for out-of-control points
`Gradient`	gradients (must be zero)
`Hessian`	Hessian matrix
`Mineigenvalue_Hessian`	Minimum eigenvalue for the Hessian matrix

Author(s)

Xinwei Huang and Takeshi Emura

References

Huang XW, Emura T (2019-), Model diagnostic procedures for copula-based Markov chain models for statistical process control, in revision

Examples

```
Y = c(0.265, 0.256, 0.261, 0.261, 0.260, 0.257, 0.258, 0.263, 0.254, 0.254,
      0.258, 0.256, 0.256, 0.265, 0.270, 0.267, 0.270, 0.267, 0.266, 0.271,
      0.270, 0.264, 0.261, 0.264, 0.266, 0.264, 0.269, 0.268, 0.264, 0.262,
      0.257, 0.255, 0.255, 0.253, 0.251, 0.254, 0.255)
Clayton.Markov2.MLE(Y, k = 1, D = 1, plot = TRUE)

Y=Clayton.Markov2.DATA(n=1000,mu=0,sigma=1,alpha=8)
Clayton.Markov2.MLE(Y, plot=TRUE)
```

Joe.Markov.DATA *Generating Time Series Data Under a Copula-Based Markov Chain Model with the Joe Copula*

Description

Time-series datasets are generated under a copula-based Markov chain model with the Joe copula.

Usage

```
Joe.Markov.DATA(n, mu, sigma, alpha)
```

Arguments

n	sample size
mu	mean
sigma	standard deviation
alpha	association parameter

Details

alpha>=1 for positive association

Value

Time series data

Author(s)

Takeshi Emura

References

Emura T, Long TH, Sun LH (2017), R routines for performing estimation and statistical process control under copula-based time series models, Communications in Statistics - Simulation and Computation, 46 (4): 3067-87

Long TS and Emura T (2014), A control chart using copula-based Markov chain models, Journal of the Chinese Statistical Association 52 (No.4): 466-96

Examples

```
n=1000
alpha=2.856 ### Kendall's tau =0.5 ###
mu=2
sigma=1
Y=Joe.Markov.DATA(n,mu,sigma,alpha)
mean(Y)
sd(Y)
cor(Y[-1],Y[-n],method="kendall")

Joe.Markov.MLE(Y,k=2)
```

Joe.Markov.DATA.binom *Generating Time Series Data Under a Copula-Based Markov Chain Model with the Joe Copula and Binomial Margin.*

Description

Time-series datasets are generated under a copula-based Markov chain model with the Joe copula and binomial margin.

Usage

```
Joe.Markov.DATA.binom(n, size, prob, alpha)
```

Arguments

n	number of observations
size	number of binomial trials
prob	binomial probability; 0<p<1
alpha	association parameter

Details

alpha>=1 for positive association

Value

time series data

Author(s)

Huang X, Emura T

References

Chen W (2018) Copula-based Markov chain model with binomial data, NCU Library

Huang X, Chen W, Emura T (2019-) A control chart using a copula-based Markov chain for attribute data, revision

Examples

```
size=50
prob=0.5
alpha=2
set.seed(1)
Y=Joe.Markov.DATA.binom(n=500,size,prob,alpha)
### sample mean and SD ###
mean(Y)
sd(Y)
### true mean and SD ###
size*prob
sqrt(size*prob*(1-prob))
```

`Joe.Markov.MLE` *Maximum Likelihood Estimation and Statistical Process Control Under the Joe Copula*

Description

The maximum likelihood estimates are produced and the Shewhart control chart is drawn with k-sigma control limits (e.g., 3-sigma). The dependence model follows the Joe copula and the marginal (stationary) distribution follows the normal distribution.

Usage

```
Joe.Markov.MLE(Y, k = 3, D = 1, plot = TRUE,GOF=FALSE)
```

Arguments

`Y`	vector of datasets
`k`	constant determining the length between LCL and UCL (k=3 corresponds to 3-sigma limit)
`D`	diameter for U(-D, D) used in randomized Newton-Raphson
`plot`	show the control chart if TRUE
`GOF`	show the model diagnostic plot if TRUE

Value

estimates	estimates
out_of_control	IDs for out-of-control points
Gradient	gradients (must be zero)
Hessian	Hessian matrix
Mineigenvalue_Hessian	Minimum eigenvalue for the Hessian matrix
CM.test	Cramer-von Mises test statistics
KS.test	Kolmogorov-Smirnov test statistics

Author(s)

Takeshi Emura

References

Emura T, Long TH, Sun LH (2017), R routines for performing estimation and statistical process control under copula-based time series models, Communications in Statistics - Simulation and Computation, 46 (4): 3067-87

Long TH and Emura T (2014), A control chart using copula-based Markov chain models, Journal of the Chinese Statistical Association 52 (No.4): 466-96

Examples

```
n=1000
alpha=2.856 ### Kendall's tau =0.5 ###
mu=2
sigma=1
Y=Joe.Markov.DATA(n,mu,sigma,alpha)
mean(Y)
sd(Y)
cor(Y[-1],Y[-n],method="kendall")

Joe.Markov.MLE(Y,k=2)
```

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