Package: Copula.Markov (via r-universe)

June 3, 2026

Type Package

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

Version 2.9

Date 2021-11-29

Author Takeshi Emura, Xinwei Huang, Ting-Hsuan Long, Li-Hsien Sun

Maintainer Takeshi Emura <takeshiemura@gmail.com>

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 (2021 Commun Stat-Simul) <DOI:10.1080/03610918.2019.1602647>, Lin et al. (2021 Comm Stat-Simul) <DOI:10.1080/03610918.2019.1652318>, Sun et al. (2020 JSS Series in Statistics)<DOI:10.1007/978-981-15-4998-4>, and Huang and Emura (2021, in revision).

NeedsCompilation no

Repository https://takeshiemura1.r-universe.dev

Date/Publication 2021-11-29 04:40:13 UTC

RemoteUrl https://github.com/cran/Copula.Markov

RemoteRef HEAD

RemoteSha f27c0753c1d586d5c12f1579ddba6754d84f64b4

Contents

Copula.Markov-package 2
Clayton.Markov.DATA 3
Clayton.Markov.DATA.binom 4
Clayton.Markov.GOF 5
Clayton.Markov.GOF.binom 6

Clayton.Markov.MLE 7
Clayton.Markov.MLE.binom 9
Clayton.Markov2.DATA 10
Clayton.Markov2.MLE 11
Clayton.MixNormal.Markov.MLE 12
DowJones 13
Joe.Markov.DATA 14
Joe.Markov.DATA.binom 15
Joe.Markov.GOF.binom 16
Joe.Markov.MLE 17
Joe.Markov.MLE.binom 19

Index **21**

`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:	2.9
Date:	2021-11-29
License: GPL-2	

Author(s)

Emura T, Huang XW, Chen WR, Long TH, Sun LH. Maintainer: Takeshi Emura <takeshiemura@gmail.com>

References

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

Huang XW, Emura T (2021-), Computational methods for a copula-based Markov chain model with a binomial time series, in review

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(4):466-96

Lin WC, Emura T, Sun LH (2021), Estimation under copula-based Markov normal mixture models for serially correlated data, Communications in Statistics - Simulation and Computation, 50(12):4483-515

Huang XW, Emura T (2021), Model diagnostic procedures for copula-based Markov chain models for statistical process control, Communications in Statistics - Simulation and Computation, doi: 50(8):2345-67

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

Description

Time-series data are generated under a copula-based Markov chain model with the Clayton copula. See Long et al. (2014) and Emura et al. (2017) for the details.

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 of size n.

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 data 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 of size n (this is different from the number of binomial trials = "size").

Author(s)

Huang XW, Chen W, Emura T

References

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

Huang XW, Emura T (2021-), Computational methods for a copula-based Markov chain model with a binomial time series, in review

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` *A goodness-of-fit test for the marginal normal distribution.*

Description

Perform a parametric bootstrap test based on the Cramer-von Mises and Kolmogorov-Smirnov statistics as proposed by Huang and Emura (2019).

Usage

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

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
`method`	Newton-Raphson method or nlm can be chosen

Value

`CM`	The Cramer-von Mises statistic and its P-value
`KS`	The Kolmogorov-Smirnov statistic and its P-value
`CM.boot`	Bootstrap values of the Cramer-von Mises statistics
`KS.boot`	Bootstrap values of the Kolmogorov-Smirnov 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

Huang XW, Emura T (2021), Model diagnostic procedures for copula-based Markov chain models for statistical process control, Communications in Statistics - Simulation and Computation, doi: 50(8):2345-67

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

A goodness-of-fit test for the marginal binomial distribution.

Description

Perform a parametric bootstrap test based on the Cramer-von Mises and Kolmogorov-Smirnov statistics as proposed by Huang and Emura (2019) and Huang et al. (2019-).

Usage

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

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
`method`	Newton-Raphson method or nlm can be chosen

Value

CM	The Cramer-von Mises statistic and its P-value
KS	The Kolmogorov-Smirnov statistic and its P-value
CM.boot	Bootstrap values of the Cramer-von Mises statistics
KS.boot	Bootstrap values of the Kolmogorov-Smirnov statistics

Author(s)

Huang XW, Emura T

References

Huang XW, Emura T (2021), Model diagnostic procedures for copula-based Markov chain models for statistical process control, Communications in Statistics - Simulation and Computation, doi: 50(8):2345-67

Huang XW, Emura T (2021-), Computational methods for a copula-based Markov chain model with a binomial time series, in review

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,method = "nlm")
```

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
`method`	apply "nlm" or "Newton" method

Value

`mu`	estimate, SE, and 95 percent CI
`sigma`	estimate, SE, and 95 percent CI
`alpha`	estimate, SE, and 95 percent CI
`Control_Limit`	Center = mu, LCL = mu - k*sigma, UCL = mu + k*sigma
`out_of_control`	IDs for out-of-control points
`Gradient`	gradients (must be zero)
`Hessian`	Hessian matrix
`Eigenvalue_Hessian`	Eigenvalues for the Hessian matrix
`KS.test`	KS statistics
`CM.test`	CM statistics
`log.likelihood`	Log-likelihood value for the estimation

Author(s)

Long TH, Huang XW and Emura T

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 95 percent CI
`alpha`	estimate, SE, and 95 percent CI
`Control_Limit`	Center = n*p, LCL = mu - k*sigma, UCL = mu + k*sigma
`out_of_control`	IDs for out-of-control points
`Gradient`	gradients (must be zero)
`Hessian`	Hessian matrix
`Eigenvalue_Hessian`	Eigenvalues for the Hessian matrix
`KS.test`	KS statistics
`CM.test`	CM statistics
`log_likelihood`	Log-likelihood value for the estimation

Author(s)

Huang XW, Emura T

References

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

Huang XW, Emura T (2021-), Computational methods for a copula-based Markov chain model with a binomial time series, in review

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 data 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 of size n

Author(s)

Xinwei Huang and Takeshi Emura

References

Huang XW, Emura T (2021), Model diagnostic procedures for copula-based Markov chain models for statistical process control, Communications in Statistics - Simulation and Computation, doi: 50(8):2345-67

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. The model diagnostic plot is also given (by the option "GOF=TRUE"). See Huang and Emura (2019) for the methodological details.

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

`mu`	estimate, SE, and 95 percent CI
`sigma`	estimate, SE, and 95 percent CI
`alpha`	estimate, SE, and 95 percent CI
`Control_Limit`	Center = mu, LCL = mu - k*sigma, UCL = mu + k*sigma
`out_of_control`	IDs for out-of-control points
`Gradient`	gradients (must be zero)
`Hessian`	Hessian matrix
`Eigenvalue_Hessian`	Eigenvalues for the Hessian matrix
`KS.test`	KS statistics
`CM.test`	CM statistics
`log.likelihood`	Log-likelihood value for the estimation

Author(s)

Xinwei Huang and Takeshi Emura

References

Huang XW, Emura T (2021), Model diagnostic procedures for copula-based Markov chain models for statistical process control, Communications in Statistics - Simulation and Computation, doi: 50(8):2345-67

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)
```

Clayton.MixNormal.Markov.MLE

Maximum Likelihood Estimation using Newton-Raphson Method Under the Clayton Copula and the Mix-Normal distribution

---

Description

The maximum likelihood estimates are produced. The dependence model follows the Clayton copula and the marginal distribution follows the Mix-Normal distribution.

Usage

```
Clayton.MixNormal.Markov.MLE(y)
```

Arguments

`y`	vector of datasets

Value

`alpha`	estimate, SE, and 95 percent CI
`mu1`	estimate, SE, and 95 percent CI
`mu2`	estimate, SE, and 95 percent CI
`sigma1`	estimate, SE, and 95 percent CI
`sigma2`	estimate, SE, and 95 percent CI
`p`	estimate, SE, and 95 percent CI

`Gradient` gradients (must be zero)

`Hessian` Hessian matrix

`Eigenvalue_Hessian` Eigenvalues for the Hessian matrix

`log.likelihood` Log-likelihood value for the estimation

Author(s)

Sun LH, Huang XW

References

Lin WC, Emura T, Sun LH (2021), Estimation under copula-based Markov normal mixture models for serially correlated data, Communications in Statistics - Simulation and Computation, 50(12):4483-515

Examples

```
data(DowJones)
Y=as.vector(DowJones$log_return)
Clayton.MixNormal.Markov.MLE(y=Y)
```

DowJones *Dow Jones Industrial Average*

Description

The log return of weekly stock price of Dow Jones Industrial Average from 2008/1/1 to 2012/1/1.

Usage

```
data("DowJones")
```

Format

A data frame with 754 observations on the following 1 variables.

`log_return` a numeric vector

References

Lin WC, Emura T, Sun LH (2021), Estimation under copula-based Markov normal mixture models for serially correlated data, Communications in Statistics - Simulation and Computation, 50(12):4483-515

Examples

```
data(DowJones)
DowJones
```

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

Description

Time-series data 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 of size n

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 data 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 XW, Emura T (2021-), Computational methods for a copula-based Markov chain model with a binomial time series, in review

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.GOF.binom *A goodness-of-fit test for the marginal binomial distribution.*

Description

Perform a parametric bootstrap test based on the Cramer-von Mises and Kolmogorov-Smirnov statistics as proposed by Huang and Emura (2019) and Huang et al. (2019-).

Usage

```
Joe.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`	The Cramer-von Mises statistic and its P-value
`KS`	The Kolmogorov-Smirnov statistic and its P-value
`CM.boot`	Bootstrap values of the Cramer-von Mises statistics
`KS.boot`	Bootstrap values of the Kolmogorov-Smirnov statistics

Author(s)

Huang XW, Emura T

References

Huang XW, Emura T (2021), Model diagnostic procedures for copula-based Markov chain models for statistical process control, Communications in Statistics - Simulation and Computation, doi: 50(8):2345-67

Huang XW, Emura T (2021-), Computational methods for a copula-based Markov chain model with a binomial time series, in review

Examples

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

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,method = "nlm")
```

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
`method`	apply "nlm" or "Newton" method

Value

mu	estimate, SE, and 95 percent CI
sigma	estimate, SE, and 95 percent CI
alpha	estimate, SE, and 95 percent CI
Control_Limit	Center = mu, LCL = mu - k*sigma, UCL = mu + k*sigma
out_of_control	IDs for out-of-control points
Gradient	gradients (must be zero)
Hessian	Hessian matrix
Eigenvalue_Hessian	Eigenvalues for the Hessian matrix
KS.test	KS statistics
CM.test	CM statistics
log.likelihood	Log-likelihood value for the estimation

Author(s)

Long TH, Huang XW and 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)
```

`Joe.Markov.MLE.binom` *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 binomial distribution.

Usage

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

Arguments

`Y`	vector of observations
`size`	number of binomial trials
`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 95 percent CI
`alpha`	estimate, SE, and 95 percent CI
`Control_Limit`	Center = n*p, LCL = mu - k*sigma, UCL = mu + k*sigma
`out_of_control`	IDs for out-of-control points
`Gradient`	gradients (must be zero)
`Hessian`	Hessian matrix
`Eigenvalue_Hessian`	Eigenvalues for the Hessian matrix
`KS.test`	KS statistics
`CM.test`	CM statistics
`log_likelihood`	Log-likelihood value for the estimation

Author(s)

Huang XW, Emura T

References

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

Huang XW, Emura T (2021+), Computational methods for a copula-based Markov chain model with a binomial time series, under review

Examples

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

Index

∗ **Binomial distribution**
Clayton.Markov.DATA.binom, 4
Clayton.Markov.GOF.binom, 6
Clayton.Markov.MLE.binom, 9
Joe.Markov.DATA.binom, 15
Joe.Markov.GOF.binom, 16
Joe.Markov.MLE.binom, 19
∗ **Clayton copula**
Clayton.Markov.DATA, 3
Clayton.Markov.DATA.binom, 4
Clayton.Markov.GOF, 5
Clayton.Markov.GOF.binom, 6
Clayton.Markov.MLE, 7
Clayton.Markov.MLE.binom, 9
Clayton.Markov2.DATA, 10
Clayton.Markov2.MLE, 11
Clayton.MixNormal.Markov.MLE, 12
∗ **Data generation**
Clayton.Markov.DATA, 3
Clayton.Markov.DATA.binom, 4
Clayton.Markov2.DATA, 10
Joe.Markov.DATA, 14
Joe.Markov.DATA.binom, 15
∗ **Goodness-of-fit**
Clayton.Markov.GOF, 5
Clayton.Markov.GOF.binom, 6
Joe.Markov.GOF.binom, 16
∗ **Joe copula**
Joe.Markov.DATA, 14
Joe.Markov.DATA.binom, 15
Joe.Markov.GOF.binom, 16
Joe.Markov.MLE, 17
Joe.Markov.MLE.binom, 19
∗ **MLE**
Clayton.Markov.MLE, 7
Clayton.Markov.MLE.binom, 9
Clayton.Markov2.MLE, 11
Clayton.MixNormal.Markov.MLE, 12
Joe.Markov.MLE, 17
Joe.Markov.MLE.binom, 19
∗ **Normal distribution**
Clayton.Markov.GOF, 5
∗ **Second-order model**
Clayton.Markov2.DATA, 10
Clayton.Markov2.MLE, 11
∗ **package**
Copula.Markov-package, 2
∗ **stock price**
DowJones, 13

Clayton.Markov.DATA, 3
Clayton.Markov.DATA.binom, 4
Clayton.Markov.GOF, 5
Clayton.Markov.GOF.binom, 6
Clayton.Markov.MLE, 7
Clayton.Markov.MLE.binom, 9
Clayton.Markov2.DATA, 10
Clayton.Markov2.MLE, 11
Clayton.MixNormal.Markov.MLE, 12
Copula.Markov *(*Copula.Markov-package*)*, 2
Copula.Markov-package, 2

DowJones, 13

Joe.Markov.DATA, 14
Joe.Markov.DATA.binom, 15
Joe.Markov.GOF.binom, 16
Joe.Markov.MLE, 17
Joe.Markov.MLE.binom, 19