

# Package ‘Copula.surv’

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**Type** Package

**Title** Analysis of Bivariate Survival Data Based on Copulas

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**Description** Simulating bivariate survival data from copula models.

Estimation of the association parameter in copula models.

Two different ways to estimate the association parameter in copula models are implemented.

A goodness-of-fit test for a given copula model is implemented.

See Emura, Lin and Wang (2010) <[doi:10.1016/j.csda.2010.03.013](https://doi.org/10.1016/j.csda.2010.03.013)> for details.

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Copula.surv-package     *Analysis of Bivariate Survival Data*

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### Description

Simulating bivariate survival data from copula models (Emura et al. 2019). Estimation of the association parameter in copula models. Two different ways to estimate the association parameter in copula models are implemented. A goodness-of-fit test for a given copula model is implemented. See Emura, Lin and Wang (2010) <doi:10.1016/j.csda.2010.03.013> for details. Also, Weibull regression is implemented (Section 2.6.3 of Emura et al. (2019)).

### Details

Details are seen from the references.

### Author(s)

Takeshi Emura Maintainer: Takeshi Emura <takeshiemura@gmail.com>

### References

Emura T, Lin CW, Wang W (2010) A goodness-of-fit test for Archimedean copula models in the presence of right censoring, *Compt Stat Data Anal* 54: 3033-43

Emura T, Matsui S, Rondeau V (2019), *Survival Analysis with Correlated Endpoints, Joint Frailty-Copula Models*, JSS Research Series in Statistics, Springer

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simu.BB1     *Simulating data from the BB1 copula*

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### Description

$n$  pairs of  $(U,V)$  are generated from the BB1 copula.  $n$  pairs of  $(X,Y)$  are generated from the corresponding bivariate survival model with the Weibull marginal distributions. The default parameters ( $scale1=scale2=shape1=shape2=1$ ) give the unit exponential distributions.

### Usage

```
simu.BB1(n,alpha,d=0,scale1=1,scale2=1,shape1=1,shape2=1,Print=FALSE)
```

**Arguments**

n	sample size
alpha	association (copula) parameter
d	BB1 copula's departure parameter from the Clayton (d=0 is the default)
scale1	scale parameter for X
scale2	scale parameter for Y
shape1	shape parameter for X
shape2	shape parameter for Y
Print	print Kendall's tau and means of X and Y if "TRUE"

**Details**

See Section 2.6 of Emura et al.(2019) for copulas and bivariate survival times.

**Value**

U	uniformly distributed on (0,1)
V	uniformly distributed on (0,1)
X	Weibull distributed (scale1, shape1)
Y	Weibull distributed (scale2, shape2)

**Author(s)**

Takeshi Emura

**References**

Emura T, Lin CW, Wang W (2010) A goodness-of-fit test for Archimedean copula models in the presence of right censoring, *Compt Stat Data Anal* 54: 3033-43

Emura T, Matsui S, Rondeau V (2019), *Survival Analysis with Correlated Endpoints, Joint Frailty-Copula Models*, JSS Research Series in Statistics, Springer

**Examples**

```
n=100
Dat=simu.BB1(n=n,alpha=1,d=2,scale1=1,scale2=2,shape1=0.5,shape2=2)
plot(Dat[, "U"],Dat[, "V"])
cor(Dat[, "U"],Dat[, "V"],method="kendall")
plot(Dat[, "X"],Dat[, "Y"])
cor(Dat[, "X"],Dat[, "Y"],method="kendall")
```

---

 simu.Clayton

 Simulating data from the Clayton copula
 

---

### Description

$n$  pairs of  $(U, V)$  are generated from the Clayton copula.  $n$  pairs of  $(X, Y)$  are generated from the corresponding bivariate survival model with the Weibull marginal distributions. The default parameters ( $\text{scale1}=\text{scale2}=\text{shape1}=\text{shape2}=1$ ) give the unit exponential distributions.

### Usage

```
simu.Clayton(n, alpha, scale1=1, scale2=1, shape1=1, shape2=1, Print=FALSE)
```

### Arguments

<code>n</code>	sample size
<code>alpha</code>	association (copula) parameter
<code>scale1</code>	scale parameter for $X$
<code>scale2</code>	scale parameter for $Y$
<code>shape1</code>	shape parameter for $X$
<code>shape2</code>	shape parameter for $Y$
<code>Print</code>	print Kendall's tau and means of $X$ and $Y$ if "TRUE"

### Details

See Section 2.6 of Emura et al.(2019) for copulas and bivariate survival times.

### Value

<code>U</code>	uniformly distributed on $(0,1)$
<code>V</code>	uniformly distributed on $(0,1)$
<code>X</code>	Weibull distributed ( $\text{scale1}$ , $\text{shape1}$ )
<code>Y</code>	Weibull distributed ( $\text{scale2}$ , $\text{shape2}$ )

### Author(s)

Takeshi Emura

### References

Emura T, Lin CW, Wang W (2010) A goodness-of-fit test for Archimedean copula models in the presence of right censoring, *Compt Stat Data Anal* 54: 3033-43

Emura T, Matsui S, Rondeau V (2019), *Survival Analysis with Correlated Endpoints, Joint Frailty-Copula Models*, JSS Research Series in Statistics, Springer

**Examples**

```
n=100
Dat=simu.Clayton(n=n,alpha=1,scale1=1,scale2=2,shape1=0.5,shape2=2)
plot(Dat[, "U"],Dat[, "V"])
cor(Dat[, "U"],Dat[, "V"],method="kendall")
plot(Dat[, "X"],Dat[, "Y"])
cor(Dat[, "X"],Dat[, "Y"],method="kendall")
```

simu.FGM

*Simulating data from the FGM copula***Description**

n pairs of (U,V) are generated from the FGM copula. n pairs of (X,Y) are generated from the corresponding bivariate survival model with the Weibull marginal distributions. The default parameters (scale1=scale2=shape1=shape2=1) give the unit exponential distributions.

**Usage**

```
simu.FGM(n,alpha,scale1=1,scale2=1,shape1=1,shape2=1,Print=FALSE)
```

**Arguments**

n	sample size
alpha	association (copula) parameter; $-1 \leq \alpha \leq 1$
scale1	scale parameter for X
scale2	scale parameter for Y
shape1	shape parameter for X
shape2	shape parameter for Y
Print	print Kendall's tau and means of X and Y if "TRUE"

**Details**

See Section 2.6 of Emura et al.(2019) for copulas and bivariate survival times.

**Value**

U	uniformly distributed on (0,1)
V	uniformly distributed on (0,1)
X	Weibull distributed (scale1, shape1)
Y	Weibull distributed (scale2, shape2)

**Author(s)**

Takeshi Emura

## References

Emura T, Lin CW, Wang W (2010) A goodness-of-fit test for Archimedean copula models in the presence of right censoring, *Compt Stat Data Anal* 54: 3033-43

Emura T, Matsui S, Rondeau V (2019), *Survival Analysis with Correlated Endpoints, Joint Frailty-Copula Models*, JSS Research Series in Statistics, Springer

## Examples

```
n=100
Dat=simu.FGM(n=n, alpha=1, scale1=1, scale2=2, shape1=0.5, shape2=2)
plot(Dat[, "U"], Dat[, "V"])
cor(Dat[, "U"], Dat[, "V"], method="kendall")
plot(Dat[, "X"], Dat[, "Y"])
cor(Dat[, "X"], Dat[, "Y"], method="kendall")
```

---

simu.Frank

*Simulating data from the Frank copula*

---

## Description

$n$  pairs of  $(U, V)$  are generated from the Frank copula.  $n$  pairs of  $(X, Y)$  are generated from the corresponding bivariate survival model with the Weibull marginal distributions. The default parameters ( $scale1=scale2=shape1=shape2=1$ ) give the unit exponential distributions.

## Usage

```
simu.Frank(n, alpha, scale1=1, scale2=1, shape1=1, shape2=1, Print=FALSE)
```

## Arguments

<code>n</code>	sample size
<code>alpha</code>	association (copula) parameter
<code>scale1</code>	scale parameter for $X$
<code>scale2</code>	scale parameter for $Y$
<code>shape1</code>	shape parameter for $X$
<code>shape2</code>	shape parameter for $Y$
<code>Print</code>	print Kendall's tau and means of $X$ and $Y$ if "TRUE"

## Details

See Section 2.6 of Emura et al.(2019) for copulas and bivariate survival times.

**Value**

U	uniformly distributed on (0,1)
V	uniformly distributed on (0,1)
X	Weibull distributed (scale1, shape1)
Y	Weibull distributed (scale2, shape2)

**Author(s)**

Takeshi Emura

**References**

Emura T, Lin CW, Wang W (2010) A goodness-of-fit test for Archimedean copula models in the presence of right censoring, *Compt Stat Data Anal* 54: 3033-43

Emura T, Matsui S, Rondeau V (2019), *Survival Analysis with Correlated Endpoints, Joint Frailty-Copula Models*, JSS Research Series in Statistics, Springer

**Examples**

```
n=100
Dat=simu.Frank(n=n,alpha=10,scale1=1,scale2=2,shape1=0.5,shape2=2)
plot(Dat[, "U"],Dat[, "V"])
cor(Dat[, "U"],Dat[, "V"],method="kendall")
plot(Dat[, "X"],Dat[, "Y"])
cor(Dat[, "X"],Dat[, "Y"],method="kendall")
```

---

simu.GB

*Simulating data from the Gumbel-Barnett (GB) copula*

---

**Description**

n pairs of (U,V) are generated from the GB copula. n paris of (X,Y) are generated from the corresponding bivariate survival model with the Weibull marginal distributions. The default parameters (scale1=scale2=shape1=shape2=1) give the unit exponential distributions.

**Usage**

```
simu.GB(n,alpha,scale1=1,scale2=1,shape1=1,shape2=1,Print=FALSE)
```

**Arguments**

n	sample size
alpha	association (copula) parameter, $0 \leq \alpha \leq 1$
scale1	scale parameter for X
scale2	scale parameter for Y
shape1	shape parameter for X
shape2	shape parameter for Y
Print	print Kendall's tau and means of X and Y if "TRUE"

**Details**

See Section 2.6 of Emura et al.(2019) for copulas and bivariate survival times.

**Value**

U	uniformly distributed on (0,1)
V	uniformly distributed on (0,1)
X	Weibull distributed (scale1, shape1)
Y	Weibull distributed (scale2, shape2)

**Author(s)**

Takeshi Emura

**References**

Emura T, Lin CW, Wang W (2010) A goodness-of-fit test for Archimedean copula models in the presence of right censoring, *Compt Stat Data Anal* 54: 3033-43

Emura T, Matsui S, Rondeau V (2019), *Survival Analysis with Correlated Endpoints, Joint Frailty-Copula Models*, JSS Research Series in Statistics, Springer

**Examples**

```
n=100
Dat=simu.GB(n=n,alpha=1,scale1=1,scale2=2,shape1=0.5,shape2=2)
plot(Dat[, "U"],Dat[, "V"])
cor(Dat[, "U"],Dat[, "V"],method="kendall")
plot(Dat[, "X"],Dat[, "Y"])
cor(Dat[, "X"],Dat[, "Y"],method="kendall")
```

---

simu.Gumbel

*Simulating data from the Gumbel copula*

---

**Description**

n pairs of (U,V) are generated from the Gumbel copula. n paris of (X,Y) are generated from the corresponding bivariate survival model with the Weibull marginal distributions. The default parameters (scale1=scale2=shape1=shape2=1) give the unit exponential distributions.

**Usage**

```
simu.Gumbel(n,alpha,scale1=1,scale2=1,shape1=1,shape2=1,Print=FALSE)
```



**Arguments**

n	sample size
alpha	association (copula) parameter
scale1	scale parameter for X
scale2	scale parameter for Y
shape1	shape parameter for X
shape2	shape parameter for Y
Print	print Kendall's tau and means of X and Y if "TRUE"

**Details**

See Section 2.6 of Emura et al.(2019) for copulas and bivariate survival times.

**Value**

U	uniformly distributed on (0,1)
V	uniformly distributed on (0,1)
X	Weibull distributed (scale1, shape1)
Y	Weibull distributed (scale2, shape2)

**Author(s)**

Takeshi Emura

**References**

Emura T, Lin CW, Wang W (2010) A goodness-of-fit test for Archimedean copula models in the presence of right censoring, *Compt Stat Data Anal* 54: 3033-43

Emura T, Matsui S, Rondeau V (2019), *Survival Analysis with Correlated Endpoints, Joint Frailty-Copula Models*, JSS Research Series in Statistics, Springer

**Examples**

```
n=100
Dat=simu.Gumbel(n=n,alpha=1,scale1=1,scale2=2,shape1=0.5,shape2=2)
plot(Dat[,"U"],Dat[,"V"])
cor(Dat[,"U"],Dat[,"V"],method="kendall")
plot(Dat[,"X"],Dat[,"Y"])
cor(Dat[,"X"],Dat[,"Y"],method="kendall")
```

---

 Test.Clayton

*A goodness-of-fit test for the Clayton copula*


---

**Description**

Perform a goodness-of-fit test for the Clayton copula based on Emura, Lin and Wang (2010). The test is asymptotically equivalent to the test of Shih (1998).

**Usage**

```
Test.Clayton(x.obs,y.obs,dx,dy,lower=0.001,upper=50,U.plot=TRUE)
```

**Arguments**

x.obs	censored times for X
y.obs	censored times for Y
dx	censoring indicators for X
dy	censoring indicators for Y
lower	lower bound for the association parameter
upper	upper bound for the association parameter
U.plot	if TRUE, draw the plot of $U_1(\theta)$

**Details**

See the references.

**Value**

theta1	association parameter by the pseudo-likelihood estimator
theta2	association parameter by the unweighted estimator
Stat	$\log(\theta_1) - \log(\theta_2)$
Z	Z-value of the goodness-of-fit for the Clayton copula
P	P-value of the goodness-of-fit for the Clayton copula

**Author(s)**

Takeshi Emura

**References**

Emura T, Lin CW, Wang W (2010) A goodness-of-fit test for Archimedean copula models in the presence of right censoring, *Compt Stat Data Anal* 54: 3033-43

Shih JH (1998) A goodness-of-fit test for association in a bivariate survival model. *Biometrika* 85: 189-200

**Examples**

```

n=20
theta_true=2 ## association parameter ##
r1_true=2 ## hazard for X
r2_true=2 ## hazard for Y

set.seed(1)
V1=runif(n)
V2=runif(n)
X=-1/r1_true*log(1-V1)
W=(1-V1)^(-theta_true)
Y=1/theta_true/r2_true*log( 1-W+W*(1-V2)^(-theta_true/(theta_true+1)) )
C=runif(n,min=0,max=5)

x.obs=pmin(X,C)
y.obs=pmin(Y,C)
dx=X<=C
dy=Y<=C

Test.Clayton(x.obs,y.obs,dx,dy)

```

---

Test.Gumbel

*A goodness-of-fit test for the Gumbel copula*


---

**Description**

Perform a goodness-of-fit test for the Gumbel copula based on Emura, Lin and Wang (2010).

**Usage**

```
Test.Gumbel(x.obs,y.obs,dx,dy,lower=0.01,upper=50,U.plot=TRUE)
```

**Arguments**

x.obs	censored times for X
y.obs	censored times for Y
dx	censoring indicators for X
dy	censoring indicators for Y
lower	lower bound for the association parameter
upper	upper bound for the association parameter
U.plot	if TRUE, draw the plot of $U_1(\theta)$ and $U_2(\theta)$

**Details**

See the references.

**Value**

theta1	association parameter by the pseudo-likelihood estimator
theta2	association parameter by the unweighted estimator
Stat	$\log(\theta_1) - \log(\theta_2)$
Z	Z-value of the goodness-of-fit for the Clayton copula
P	P-value of the goodness-of-fit for the Clayton copula

**Author(s)**

Takeshi Emura

**References**

Emura T, Lin CW, Wang W (2010) A goodness-of-fit test for Archimedean copula models in the presence of right censoring, *Compt Stat Data Anal* 54: 3033-43

**Examples**

```
x.obs=c(1,2,3,4,5,6,7,8,9,10,11,12,13,14,15)
y.obs=c(2,1,4,5,6,8,3,7,10,9,11,12,13,14,15)
dx=c(1,1,1,1,1,1,1,1,1,1,1,1,1,1,1)
dy=c(1,1,1,1,1,1,1,1,1,1,1,1,1,1,1)
Test.Gumbel(x.obs,y.obs,dx,dy)
```

---

U1.Clayton

*Estimation of an association parameter via the pseudo-likelihood*

---

**Description**

Estimate the association parameter of the Clayton copula using bivariate survival data. The estimator was derived by Clayton (1978) and reformulated by Emura, Lin and Wang (2010).

**Usage**

```
U1.Clayton(x.obs,y.obs,dx,dy,lower=0.001,upper=50,U.plot=TRUE)
```

**Arguments**

x.obs	censored times for X
y.obs	censored times for Y
dx	censoring indicators for X
dy	censoring indicators for Y
lower	lower bound for the association parameter
upper	upper bound for the association parameter
U.plot	if TRUE, draw the plot of $U_{-1}(\theta)$

**Details**

Details are seen from the references.

**Value**

theta	association parameter
tau	Kendall's tau ( $=\text{theta}/(\text{theta}+2)$ )

**Author(s)**

Takeshi Emura

**References**

Clayton DG (1978). A model for association in bivariate life tables and its application to epidemiological studies of familial tendency in chronic disease incidence. *Biometrika* 65: 141-51.

Emura T, Lin CW, Wang W (2010) A goodness-of-fit test for Archimedean copula models in the presence of right censoring, *Compt Stat Data Anal* 54: 3033-43

**Examples**

```
n=200
theta_true=2 ## association parameter ##
r1_true=1 ## hazard for X
r2_true=1 ## hazard for Y

set.seed(1)
V1=runif(n)
V2=runif(n)
X=-1/r1_true*log(1-V1)
W=(1-V1)^(-theta_true)
Y=1/theta_true/r2_true*log( 1-W+W*(1-V2)^(-theta_true/(theta_true+1)) )
C=runif(n,min=0,max=5)

x.obs=pmin(X,C)
y.obs=pmin(Y,C)
dx=X<=C
dy=Y<=C

U1.Clayton(x.obs,y.obs,dx,dy)
```

---

U1.Gumbel

*Estimation of an association parameter via the unweighted estimator*

---

**Description**

Estimate the association parameter of the Gumbel copula using bivariate survival data. The estimator was derived by Emura, Lin and Wang (2010).



---

U2.Clayton

*Estimation of an association parameter via the unweighted estimator*

---

### Description

Estimate the association parameter of the Clayton copula using bivariate survival data. The estimator was defined as the unweighted estimator in Emura, Lin and Wang (2010).

### Usage

```
U2.Clayton(x.obs, y.obs, dx, dy)
```

### Arguments

x.obs	censored times for X
y.obs	censored times for Y
dx	censoring indicators for X
dy	censoring indicators for Y

### Details

Details are seen from the references.

### Value

theta	association parameter
tau	Kendall's tau ( $=\theta/(\theta+2)$ )

### Author(s)

Takeshi Emura

### References

Emura T, Lin CW, Wang W (2010) A goodness-of-fit test for Archimedean copula models in the presence of right censoring, *Compt Stat Data Anal* 54: 3033-43

### Examples

```
n=200
theta_true=2 ## association parameter ##
r1_true=1 ## hazard for X
r2_true=1 ## hazard for Y

set.seed(1)
V1=runif(n)
V2=runif(n)
```

```

X=-1/r1_true*log(1-V1)
W=(1-V1)^(-theta_true)
Y=1/theta_true/r2_true*log( 1-W+W*(1-V2)^(-theta_true/(theta_true+1)) )
C=runif(n,min=0,max=5)

x.obs=pmin(X,C)
y.obs=pmin(Y,C)
dx=X<=C
dy=Y<=C

U2.Clayton(x.obs,y.obs,dx,dy)

```

---

U2.Gumbel

*Estimation of an association parameter via the pseudo-likelihood*


---

### Description

Estimate the association parameter of the Gumbel copula using bivariate survival data. The estimator was derived by Emura, Lin and Wang (2010).

### Usage

```
U2.Gumbel(x.obs,y.obs,dx,dy,lower=0.01,upper=50,U.plot=TRUE)
```

### Arguments

x.obs	censored times for X
y.obs	censored times for Y
dx	censoring indicators for X
dy	censoring indicators for Y
lower	lower bound for the association parameter
upper	upper bound for the association parameter
U.plot	if TRUE, draw the plot of $U_1(\theta)$

### Details

Details are seen from the references.

### Value

theta	association parameter
tau	Kendall's tau ( $=\theta/(\theta+1)$ )

### Author(s)

Takeshi Emura



**References**

Emura T, Lin CW, Wang W (2010) A goodness-of-fit test for Archimedean copula models in the presence of right censoring, *Compt Stat Data Anal* 54: 3033-43

**Examples**

```
x.obs=c(1,2,3,4,5)
y.obs=c(2,1,4,5,6)
dx=c(1,1,1,1,1)
dy=c(1,1,1,1,1)
U2.Gumbel(x.obs,y.obs,dx,dy)
```

---

Weib.reg.BB1

*Weibull regression under the BB1 copula*


---

**Description**

See Section 2.6.3 of Emura et al. (2019).

**Usage**

```
Weib.reg.BB1(x.obs,y.obs,dx,dy,zx,zy,convergence.par=FALSE)
```

**Arguments**

x.obs	censored times for X
y.obs	censored times for Y
dx	censoring indicators for X
dy	censoring indicators for Y
zx	matrix of covariates for X
zy	matrix of covariates for Y
convergence.par	if TRUE, show the details

**Details**

Details are seen from the references.

**Value**

beta_x	regression coefficients for X
beta_y	regression coefficients for Y

**Author(s)**

Takeshi Emura

**References**

Emura T, Matsui S, Rondeau V (2019), Survival Analysis with Correlated Endpoints, Joint Frailty-Copula Models, JSS Research Series in Statistics, Springer

**Examples**

```
#TBA
```

---

Weib.reg.BB1.0	<i>Weibull regression under the BB1 copula with known "delta"</i>
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---

**Description**

See Section 2.6.3 of Emura et al. (2019).

**Usage**

```
Weib.reg.BB1.0(x.obs,y.obs,dx,dy,zx,zy,delta=0,convergence.par=FALSE)
```

**Arguments**

x.obs	censored times for X
y.obs	censored times for Y
dx	censoring indicators for X
dy	censoring indicators for Y
zx	matrix of covariates for X
zy	matrix of covariates for Y
delta	known copula parameter ( $d \geq 0$ )
convergence.par	if TRUE, show the details

**Details**

Details are seen from the references.

**Value**

beta_x	regression coefficients for X
beta_y	regression coefficients for Y

**Author(s)**

Takeshi Emura

**References**

Emura T, Matsui S, Rondeau V (2019), Survival Analysis with Correlated Endpoints, Joint Frailty-Copula Models, JSS Research Series in Statistics, Springer

**Examples**

```
#TBA
```

---

Weib.reg.Clayton	<i>Weibull regression under the Clayton copula</i>
------------------	--

---

**Description**

See Section 2.6.3 of Emura et al. (2019).

**Usage**

```
Weib.reg.Clayton(x.obs,y.obs,dx,dy,zx,zy,convergence.par=FALSE)
```

**Arguments**

x.obs	censored times for X
y.obs	censored times for Y
dx	censoring indicators for X
dy	censoring indicators for Y
zx	matrix of covariates for X
zy	matrix of covariates for Y
convergence.par	if TRUE, show the details

**Details**

Details are seen from the references.

**Value**

beta_x	regression coefficients for X
beta_y	regression coefficients for Y

**Author(s)**

Takeshi Emura

**References**

Emura T, Matsui S, Rondeau V (2019), Survival Analysis with Correlated Endpoints, Joint Frailty-Copula Models, JSS Research Series in Statistics, Springer

**Examples**

#TBA

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  - \* **Weibull distribution**
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  - \* **package**
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