

# Package ‘cenROC’

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**Type** Package

**Title** Estimating Time-Dependent ROC Curve and AUC for Censored Data

**Version** 2.0.0

## Description

Contains functions to estimate a smoothed and a non-smoothed (empirical) time-dependent receiver operating characteristic curve and the corresponding area under the receiver operating characteristic curve and the optimal cutoff point for the right and interval censored survival data. See Beyene and El Ghouh (2020) <[doi:10.1002/sim.8671](https://doi.org/10.1002/sim.8671)> and Beyene and El Ghouh (2022) <[doi:10.1002/bimj.202000382](https://doi.org/10.1002/bimj.202000382)>.

**License** GPL (>= 2)

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cenROC	<i>Estimation of the time-dependent ROC curve for right censored survival data</i>
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## Description

This function computes the time-dependent ROC curve for right censored survival data using the cumulative sensitivity and dynamic specificity definitions. The ROC curves can be either empirical (non-smoothed) or smoothed with/without boundary correction. It also calculates the time-dependent area under the ROC curve (AUC).

## Usage

```
cenROC(Y, M, censor, t, U = NULL, h = NULL, bw = "NR", method = "tra",
       ktype = "normal", ktype1 = "normal", B = 0, alpha = 0.05, plot = "TRUE")
```

## Arguments

Y	The numeric vector of event-times or observed times.
M	The numeric vector of marker values for which the time-dependent ROC curves is computed.
censor	The censoring indicator, 1 if event, 0 otherwise.
t	A scalar time point at which the time-dependent ROC curve is computed.
U	The vector of grid points where the ROC curve is estimated. The default is a sequence of 151 numbers between 0 and 1.
h	A scalar for the bandwidth of Beran's weight calculations. The default is the value obtained by using the method of Sheather and Jones (1991).
bw	A character string specifying the bandwidth estimation method for the ROC itself. The possible options are "NR" for the normal reference, the plug-in "PI" and the cross-validation "CV". The default is the "NR" normal reference method. The user can also introduce a numerical value.
method	The method of ROC curve estimation. The possible options are "emp" empirical method; "untra" smooth without boundary correction and "tra" is smooth ROC curve estimation with boundary correction. The default is the "tra" smooth ROC curve estimate with boundary correction.
ktype	A character string giving the type kernel distribution to be used for smoothing the ROC curve: "normal", "epanechnikov", "biweight", or "triweight". By default, the "normal" kernel is used.

ktype1	A character string specifying the desired kernel needed for Beran weight calculation. The possible options are "normal", "epanechnikov", "tricube", "boxcar", "triangular", or "quartic". The default is "normal" kernel density.
B	The number of bootstrap samples to be used for variance estimation. The default is 0, no variance estimation.
alpha	The significance level. The default is 0.05.
plot	The logical parameter to see the ROC curve plot. The default is TRUE.

### Details

The empirical (non-smoothed) ROC estimate and the smoothed ROC estimate with/without boundary correction can be obtained using this function. The smoothed ROC curve estimators require selecting two bandwidth parameters: one for Beran's weight calculation and one for smoothing the ROC curve. For the latter, three data-driven methods: the normal reference "NR", the plug-in "PI" and the cross-validation "CV" were implemented. To select the bandwidth parameter needed for Beran's weight calculation, by default, the plug-in method of Sheather and Jones (1991) is used but it is also possible to introduce a numeric value. See Beyene and El Ghouh (2020) for details.

### Value

Returns the following items:

ROC The vector of estimated ROC values. These will be numeric numbers between zero and one.

U The vector of grid points used.

AUC A data frame of dimension  $1 \times 4$ . The columns are: AUC, standard error of AUC, the lower and upper limits of bootstrap CI.

bw The computed value of bandwidth. For the empirical method this is always NA.

Dt The vector of estimated event status.

M The vector of Marker values.

### Author(s)

Kassu Mehari Beyene and Anouar El Ghouh

### References

Beyene, K. M. and El Ghouh A. (2020). Smoothed time-dependent receiver operating characteristic curve for right censored survival data. *Statistics in Medicine*. 39: 3373–3396.

Sheather, S. J. and Jones, M. C. (1991). A Reliable data-based bandwidth selection method for kernel density estimation. *Journal of the Royal Statistical Society. Series B (Methodological)* 53(3): 683–690.

## Examples

```
library(cenROC)

data(mayo)

est = cenROC(Y=mayo$time, M=mayo$mayoscore5, censor=mayo$censor, t=365*6)
est$AUC
```

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CV

*The cross-validation bandwidth selection for weighted data*

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## Description

This function computes the data-driven bandwidth for smoothing the ROC (or distribution) function using the CV method of Beyene and El Gouch (2020). This is an extension of the classical (unweighted) cross-validation bandwidth selection method to the case of weighted data.

## Usage

```
CV(X, wt, ktype = "normal")
```

## Arguments

X	The numeric data vector.
wt	The non-negative weight vector.
ktype	A character string giving the type kernel to be used: "normal", "epanechnikov", "biweight", or "triweight". By default, the "normal" kernel is used.

## Details

Bowman et al (1998) proposed the cross-validation bandwidth selection method for unweighted kernel smoothed distribution function. This method is implemented in the R package `kerdiest`. We adapted this for the case of weighted data by incorporating the weight variable into the cross-validation function of Bowman's method. See Beyene and El Gouch (2020) for details.

## Value

Returns the computed value for the bandwidth parameter.

## Author(s)

Kassu Mehari Beyene and Anouar El Gouch

## References

- Beyene, K. M. and El Ghouch A. (2020). Smoothed time-dependent receiver operating characteristic curve for right censored survival data. *Statistics in Medicine*. 39: 3373– 3396.
- Bowman A., Hall P. and Trvan T.(1998). Bandwidth selection for the smoothing of distribution functions. *Biometrika* 85:799-808.
- Quintela-del-Rio, A. and Estevez-Perez, G. (2015). *kerdiest*: Nonparametric kernel estimation of the distribution function, bandwidth selection and estimation of related functions. R package version 1.2.

## Examples

```
library(cenROC)

X <- rnorm(100) # random data vector
wt <- runif(100) # weight vector

## Cross-validation bandwidth selection
CV(X = X, wt = wt)$bw
```

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hds

*NASA Hypobaric Decompression Sickness Marker Data*

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## Description

This data contains the marker values with the left and right limits of the observed time for the subjects in NASA Hypobaric Decompression Sickness Data.

## Usage

```
data(hds)
```

## Format

This is a data frame with 238 observations and 3 variables: L (left limit of the observed time), R (right limit of the observed time) and M (marker). The marker is a score derived by combining the covariates Age, Sex, TR360, and Noadyn.

## References

- Beyene, K. M. and El Ghouch A. (2022). Time-dependent ROC curve estimation for interval-censored data. *Biometrical Journal*, 64, 1056– 1074.

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IntROC	<i>Time-dependent ROC curve estimation for interval-censored survival data</i>
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### Description

This function computes the time-dependent ROC curve for interval censored survival data using the cumulative sensitivity and dynamic specificity definitions. The ROC curves can be either empirical (non-smoothed) or smoothed with/without boundary correction. It also calculates the time-dependent AUC.

### Usage

```
IntROC(L, R, M, t, U = NULL, method = "emp", method2 = "pa", dist = "weibull",
       bw = NULL, ktype = "normal", len = 151, B = 0, alpha = 0.05, plot = "TRUE")
```

### Arguments

L	The numericvector of left limit of observed time. For left censored observations $L == 0$ .
R	The numericvector of right limit of observed time. For right censored observation $R == \text{inf}$ .
M	The numeric vector of marker values.
t	A scaler time point used to calculate the ROC curve.
U	The numeric vector of cutoff values.
method	The method of ROC curve estimation. The possible options are "emp" empirical metod; "untra" smooth without boundary correction and "tra" is smooth ROC curve estimation with boundary correction. The default is the "emp" empirical method.
method2	A character indication type of modeling. This include nonparametric "np", parametric "pa" and semiparametric "sp". The default is the "np" parametric with weibull distribution.
dist	A character incating the type of distribution for parametric model. This includes are "exponential", "weibull", "gamma", "lnorm", "loglogistic" and "generalgamma".
bw	A character string specifying the bandwidth estimation method. The possible options are "NR" for the normal reference, the plug-in "PI" and the cross-validation "CV". The default is the "NR" normal reference method. It is also possible to use a numeric value.
ktype	A character string giving the type kernel distribution to be used for smoothing the ROC curve: "normal", "epanechnikov", "biweight", or "triweight". By default, the "normal" kernel is used.
len	The length of the grid points for ROC estimation. Default is 151.

B	The number of bootstrap samples to be used for variance estimation. The default is 0, no variance estimation.
alpha	The significance level. The default is 0.05.
plot	The logical parameter to see the ROC curve plot. Default is TRUE.

### Details

This function implements time-dependent ROC curve and the corresponding AUC using the model-based and nonparametric for the estimation of conditional survival function. The empirical (non-smoothed) ROC estimate and the smoothed ROC estimate with/without boundary correction can be obtained using this function. The smoothed ROC curve estimators require selecting a bandwidth parameter for smoothing the ROC curve. To this end, three data-driven methods: the normal reference "NR", the plug-in "PI" and the cross-validation "CV" were implemented. See Beyene and El Ghouch (2020) for details.

### Value

Returns the following items:

ROC The vector of estimated ROC values. These will be numeric numbers between zero and one.

U The vector of grid points used.

AUC A data frame of dimension  $1 \times 4$ . The columns are: AUC, standard error of AUC, the lower and upper limits of bootstrap CI.

bw The computed value of bandwidth. For the empirical method this is always NA.

Dt The vector of estimated event status.

M The vector of Marker values.

### References

Beyene, K. M. and El Ghouch A. (2022). Time-dependent ROC curve estimation for interval-censored data. *Biometrical Journal*, 64, 1056– 1074.

Beyene, K. M. and El Ghouch A. (2020). Smoothed time-dependent receiver operating characteristic curve for right censored survival data. *Statistics in Medicine*. 39: 3373– 3396.

### Examples

```
library(cenROC)

data(hds)

est = IntROC(L=hds$L, R=hds$R, M=hds$M, t=2)
est$AUC
```

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mayo

*Mayo Marker Data*

---

### Description

Two marker values with event time and censoring status for the subjects in Mayo PBC data.

### Usage

```
data(mayo)
```

### Format

A data frame with 312 observations and 4 variables: time (event time/censoring time), censor (censoring indicator), mayoscore4, mayoscore5. The two scores are derived from 4 and 5 covariates respectively.

### References

Heagerty, P. J., and Zheng, Y. (2005). Survival model predictive accuracy and ROC curves. *Biometrics*, 61(1), 92-105.

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NR

*The normal reference bandwidth selection for weighted data*

---

### Description

This function computes the data-driven bandwidth for smoothing the ROC (or distribution) function using the NR method of Beyene and El Ghouh (2020). This is an extension of the classical (unweighted) normal reference bandwidth selection method to the case of weighted data.

### Usage

```
NR(X, wt, ktype = "normal")
```

### Arguments

X	The numeric data vector.
wt	The non-negative weight vector.
ktype	A character string giving the type kernel to be used: "normal", "epanechnikov", "biweight", or "triweight". By default, the "normal" kernel is used.

### Details

See Beyene and El Ghouh (2020) for details.

**Value**

Returns the computed value for the bandwidth parameter.

**Author(s)**

Kassu Mehari Beyene and Anouar El Ghouch

**References**

Beyene, K. M. and El Ghouch A. (2020). Smoothed time-dependent receiver operating characteristic curve for right censored survival data. *Statistics in Medicine*. 39: 3373– 3396.

**Examples**

```
library(cenROC)

X <- rnorm(100) # random data vector
wt <- runif(100) # weight vector

## Normal reference bandwidth selection
NR(X = X, wt = wt)$bw
```

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PI

*The plug-in bandwidth selection for weighted data*

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**Description**

This function computes the data-driven bandwidth for smoothing the ROC (or distribution) function using the PI method of Beyene and El Ghouch (2020). This is an extension of the classical (unweighted) direct plug-in bandwidth selection method to the case of weighted data.

**Usage**

```
PI(X, wt, ktype = "normal")
```

**Arguments**

X	The numeric vector of random variable.
wt	The non-negative weight vector.
ktype	A character string giving the type kernel to be used: "normal", "epanechnikov", "biweight", or "triweight". By default, the "normal" kernel is used.

**Details**

See Beyene and El Ghouch (2020) for details.

**Value**

Returns the computed value for the bandwidth parameter.

**Author(s)**

Kassu Mehari Beyene and Anouar El Ghouch

**References**

Beyene, K. M. and El Ghouch A. (2020). Smoothed time-dependent receiver operating characteristic curve for right censored survival data. *Statistics in Medicine*. 39: 3373– 3396.

**Examples**

```
library(cenROC)

X <- rnorm(100) # random data vector
wt <- runif(100) # weight vector

## Plug-in bandwidth selection
PI(X = X, wt = wt)$bw
```

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youden

*Computes optimal cutoff point using the Youden index criteria*

---

**Description**

This function computes the optimal cutoff point using the Youden index criteria of both right and interval censored time-to-event data. The Youden index estimator can be either empirical (non-smoothed) or smoothed with/without boundary correction.

**Usage**

```
youden(est, plot = "FALSE")
```

**Arguments**

<code>est</code>	The object returned either by <code>cenROC</code> or <code>IntROC</code> .
<code>plot</code>	The logical parameter to see the ROC curve plot along with the Youden index. The default is <code>TRUE</code> .

**Details**

In medical decision-making, obtaining the optimal cutoff value is crucial to identify subject at high risk of experiencing the event of interest. Therefore, it is necessary to select a marker value that classifies subjects into healthy and diseased groups. To this end, in the literature, several methods for selecting optimal cutoff point have been proposed. In this package, we only included the Youden index criteria.

**Value**

Returns the following items:

`Youden.index` The maximum Youden index value.

`cutopt` The optimal cutoff value.

`sens` The sensitivity corresponding to the optimal cutoff value.

`spec` The specificity corresponding to the optimal cutoff value.

**References**

Beyene, K. M. and El Ghouch A. (2022). Time-dependent ROC curve estimation for interval-censored data. *Biometrical Journal*, 64, 1056– 1074.

Youden, W.J. (1950). Index for rating diagnostic tests. *Cancer* 3, 32–35.

**Examples**

```
library(cenROC)

# Right censored data
data(mayo)

resu <- cenROC(Y=mayo$time, M=mayo$mayoscore5, censor=mayo$censor, t=365*6, plot="FALSE")
youden(resu, plot="TRUE")

# Interval censored data
data(hds)

resu1 = IntROC(L=hds$L, R=hds$R, M=hds$M, t=2)
youden(resu1, plot="TRUE")
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