# Package ‘qut’

January 19, 2021

**Type**  Package  
**Title**  Quantile Universal Threshold  
**Version**  2.2  
**Description**  Thresholding based tests for null hypothesis of the form $A\beta = c$, and the Quantile Universal Threshold (QUT) for lasso regularization of Generalized Linear Models (GLM) and square-root lasso to obtain a sparse model with a good compromise between high true positive rate and low false discovery rate. Giacobino et al. (2017) <doi:10.1214/17-EJS1366>. Sardy et al. (2017) <arXiv:1708.02908>.  
**License**  GPL-2  
**Depends**  Matrix, glmnet, lars, flare  
**NeedsCompilation**  no  
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**Repository**  CRAN  
**Date/Publication**  2021-01-19 10:00:02 UTC  

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QUT-package

Quantile Universal Threshold

Description
Selection of a threshold parameter $\lambda$ for GLM-lasso and Square-root lasso. The method consists in considering a null model, finding the theoretical distribution of the threshold parameter under the null, and setting $\lambda$ to an upper quantile of that distribution. Although this strategy does not use the data to select $\lambda$ but simply considers the behavior under the null model, it provides a theoretically and computationally sound selection.

Details

Package: QUT
Type: Package
License: GPL-2

Author(s)
Jairo Diaz Rodriguez <jairo.diaz@unige.ch>

References

affinelassotest

Affine lasso test

Description
Perform thresholding tests for null hypothesis of the form $H_0: A \beta = c$.

Usage
affinelassotest(y, Xdata, family = gaussian, alpha, beta0=NA, cc = NA, lambdas = NA, outrescale = NA, intercept = TRUE, group.sizes = rep(1, ncol(X)), A = ncol(X), LAD = FALSE, composite = TRUE, M = round(min(10000, max(1000, 1e+09/nrow(X)/ncol(X)))))
Arguments

- **y**: response variable. Quantitative for family=gaussian, or family=poisson (non-negative counts). For family=binomial should be a factor with two levels.
- **Xdata**: input matrix, of dimension n x p; each row is an observation vector.
- **family**: response type (see above). Default is gaussian.
- **alpha**: desired level of the test.
- **beta0**: if known, value of the nuisance parameter. Otherwise it takes beta0=0, and the statistic is asymptotically a pivot for non-Gaussian.
- **cc**: vector c
- **lambdas**: if not provided, the code performs M Monte Carlo simulation to obtain the empirical distribution \( \Lambda \) and the corresponding value in the \( \alpha \)-quantile for testing. Otherwise, vector with all the Monte Carlo values of lambda. Default is NA.
- **outrescale**: object containing all variables corresponding to the rescaling and test options. If not provided, this is calculated automatically with function `processX`. Default is NA.
- **intercept**: should intercept(s) be fitted (default=TRUE) or set to zero (FALSE).
- **group.sizes**: the vector of group sizes for affine group lasso. The number of elements is L and sum(group.sizes) should be equal to P. If L==P, then the lasso test is employed, otherwise group lasso. Default is no groups, so `rep(1, ncol(X))`.
- **A**: if A is a matrix it tests A beta = c. If A is a vector, then it gives the indexes of the parameters to be tested. Used if family=gaussian. Default is to test beta=0, so A=ncol(X).
- **LAD**: set TRUE if LAD lasso test. Default is FALSE
- **composite**: set TRUE if composite test (O & +). Default is TRUE
- **M**: number of Monte Carlo Simulations to estimate the distribution \( \Lambda \).

Value

- **lambda.alpha**: value of \( \lambda \) in the \( \alpha \)-quantile
- **lambda.data**: value of \( \lambda \) for the current data.
- **rejectH0**: result of the test. TRUE if H0 is rejected.
- **lambdas**: values of \( \lambda \) of the Monte Carlo simulation under the null hypothesis.
- **outrescale**: object containing all the rescaling variables.
- **pvalue**: approximate p-value for current data.

Author(s)

Sylvain Sardy and Jairo Diaz Rodriguez

References

Thresholding tests. Sylvain Sardy, Caroline Giacobino, Jairo Diaz.
Examples

```r
# Test H0:beta=0
P=200
N=20
s=1
A=P
alpha=0.05
X=matrix(rnorm(N*P),N,P)
M=100 #Leave the default or select higher value for better level.

#when H0 is not rejected
beta_scal=0
beta=c(rep(beta_scal, s), rep(0, P-s))
y=X%*%beta+rnorm(N)
out=affinelassotest(y,X,gaussian,alpha,M=M)
print(out$rejectH0)

#when H0 is rejected
beta_scal=10
beta=c(rep(beta_scal, s), rep(0, P-s))
y=X%*%beta+rnorm(N)
out=affinelassotest(y,X,gaussian,alpha,M=M)
print(out$rejectH0)
```

chemometrics

Chemometrics data set from Sardy (2008)

Description

Fuel octane level measurements with sample size \( N = 434 \) and \( P = 351 \) spectrometer measurements.

Usage

data(chemometrics)

Format

A data frame with 434 observations on the following 2 variables.

- \( y \) a numeric vector
- \( x \) a matrix with 351 columns

References


Examples

data(chemometrics)
**internetAd**

InternetAd data set from Kushmerick (1999)

**Description**

Classification of \( N = 2359 \) possible advertisements on internet pages based on \( P = 1430 \) features

**Usage**

```r
data(internetAd)
```

**Format**

A data frame with 2359 observations on the following 2 variables.

- \( y \) a numeric vector
- \( x \) a matrix with 1430 columns

**References**


**Examples**

```r
data(internetAd)
```

---

**lambdaqut**

Quantile Universal Threshold, regularization parameter for GLM-lasso

**Description**

Computes the Quantile Universal Threshold for GLM-lasso.

**Usage**

```r
lambdaqut(y, X, family = gaussian, alpha.level = 0.05, M = 1000, qut.standardize = TRUE, intercept = TRUE, no.penalty = NULL, offset = NULL, bootstrap=TRUE,beta0=NA,method='lasso',fixbeta0=FALSE)
```
Arguments

\( y \)
response variable. Quantitative for family\( = \)gaussian, or family\( = \)poisson (non-negative counts). For family\( = \)binomial should be a factor with two levels.

\( X \)
input matrix, of dimension \( n \times p \); each row is an observation vector.

family
response type (see above). Default is gaussian.

alpha.level
level, such that quantile \( \tau = (1 - \alpha \text{.level}) / \gamma \). Default is 0.05.

M
number of Monte Carlo Simulations to estimate the distribution \( \Lambda \). Default is 1000.

qut.standardize
standardize matrix \( X \) with a quantile-based standardization. Default is TRUE.

intercept
should intercept(s) be fitted (default\( = \)TRUE) or set to zero (FALSE).

no.penalty
unpenalized subset of covariates.

offset
a vector of length \( n \) that is included in the linear predictor. Useful for the "poisson" family (e.g. log of exposure time), or for refining a model by starting at a current fit. Default is NULL.

bootstrap
set TRUE if it is desired to bootstrap matrix \( X \) when computing the Quantile Universal Threshold (Random scenario). Default is TRUE.

beta0
coefficients of the unpenalized covariates for generating the null data for the Quantile Universal Threshold. By default is \( \text{NA} \) and it is estimated using the unpenalized covariates and/or the intercept if TRUE. If it is desired to set \( \beta_0 \) in advance, then it should be a vector of size the number of unpenalized covariates including the intercept if intercept\( = \)TRUE, in the same order. If there are not unpenalized covariates and intercept\( = \)TRUE, then it must be a real number.

method
objective function for the zero thresholding. Select \text{lasso} for GLM-lasso or \text{sqrtlasso} for Square-root lasso.

fixbeta0
used when \( \beta_0 \) is numeric. When TRUE, it does not estimate \( \beta_0 \) for each monte carlo simulation.

Value

\( \lambda \)
value of the Quantile Universal Threshold.

\( X_{\text{new}} \)
standardized matrix \( X \); \( X_{\text{new}} = X \times \text{scale.factor} \).

scale.factor
scale factor for \( X_{\text{new}} \).

\( \lambda_{\text{max}} \)
smallest \( \lambda \) that sets the lasso estimates to the zero vector.

\( \beta_0 \)
estimated value of the intercept when family is not gaussian.

Author(s)

Jairo Diaz
References


See Also

qut

Examples

X=matrix(rnorm(20*200),20,200)
y=rnorm(20)+1
lambda=lambdaqut(y, X, family=gaussian)

predict.qut Make predictions from a "qut" object.

Description

Similar to other predict methods, this function predicts fitted values from a fitted "qut" object

Usage

## S3 method for class 'qut'
predict(object, newx, mode = "glm", offset = NULL,...)
## S3 method for class 'qut'
coef(object, mode = "glm",...)

Arguments

object fitted "qut" model object.
newx matrix of new values for X at which predictions are to be made. Must be a matrix.
mode make predictions with lasso coefficients (type=lasso) or with fitted glm coefficients (type=glm). Default is glm.
offset if an offset is used in the fit, then one must be supplied for making predictions
... not used. Other arguments to predict.

Value

a vector/matrix of fitted values
processX

Author(s)

Jairo Diaz

See Also

qut

Examples

set.seed(1234)
x=matrix(rnorm(200*20),200,20)
y1=x[,1]*10+rnorm(100)

fit1=qut(y1,x,family=gaussian,sigma=1)
predict(fit1,newx=x[1:5,])
predict(fit1,newx=x[1:5,],mode='lasso')
y1[1:5]

coef(fit1,mode='lasso')
coef(fit1,mode='glm')

---

processX  
Process X matrix

Description

Rescales and transforms the X matrix according to the desired parameters, and sets all the options required by the test.

Usage

processX(X, family = gaussian, alpha, intercept = TRUE, group.sizes = rep(1, ncol(X)),
          A = ncol(X), LAD = FALSE, composite = TRUE,
          M = min(10000, max(1000, 1e+10/nrow(X)/ncol(X))))

Arguments

X       input matrix, of dimension n x p; each row is an observation vector.
family  response type (see above). Default is gaussian.
alpha   alpha for quantile rescaling; if alpha=0, then no rescaling.
intercept should intercept(s) be fitted (default=TRUE) or set to zero (FALSE).
group.sizes the vector of group sizes for affine group lasso. The number of elements is L and sum(group.sizes) should be equal to P. If L==P, then the lasso test is employed, otherwise group lasso. Default is no groups, so rep(1, ncol(X)).
if A is a matrix it tests A beta = c. If A is a vector, then it gives the indexes of the parameters to be tested. Used if family=gaussian. Default is to test beta=0, so A=ncol(X).

LAD
set TRUE if LAD lasso test. Default is FALSE

composite
set TRUE if composite test (O & +). Default is TRUE

M
number of Monte Carlo Simulations to estimate the distribution Λ.

Value
an object containing all the variables corresponding to the rescaling and test options.

Author(s)
Sylvain Sardy and Jairo Diaz

Examples

# Test H0:beta=0
P=200
N=20
s=1
A=P
alpha=0.05
X=matrix(rnorm(N+P),N,P)
outrescale=processX(X,gaussian,alpha)
M=100 #Leave the default or select higher value for better level.

#when H0 is not rejected
beta_scal=0
beta=c(rep(beta_scal, s), rep(0, P-s))
y=X%*%beta+rnorm(N)
out=affinelassotest(y,X,gaussian,alpha,M=M,outrescale=outrescale)
print(out$rejectH0)

#when H0 is rejected
beta_scal=10
beta=c(rep(beta_scal, s), rep(0, P-s))
y=X%*%beta+rnorm(N)
out=affinelassotest(y,X,gaussian,alpha,M=M,outrescale=outrescale)
print(out$rejectH0)

qut

Fit a low dimensional GLM or Square-root lasso using the Quantile Universal Threshold

Description
Variable selection with GLM-lasso or Square-root lasso choosing the penalty parameter λ with the Quantile Universal Threshold. The procedure goes towards sparse estimation of the coefficients for good selection of the important predictors.
Usage

qut(y,X,fit,family=gaussian,alpha.level=0.05,M=1000,qut.standardize=TRUE,
intercept=TRUE,offset=NULL,bootstrap=TRUE,sigma=ifelse(n>2*p,'ols','qut'),
lambda.min.ratio=ifelse(n<p,0.01,0.0001),nlambda=ifelse(type=='flare',2,100),
lambda=NULL,...)

Arguments

y response variable. Quantitative for family=gaussian, or family=poisson (non-negative counts). For family=binomial should be a factor with two levels.
X input matrix, of dimension n x p; each row is an observation vector.
fit a user supplied glmnet or lars object. Typical usage is to leave it empty so that the program computes the regularization path using the algorithm selected in type. WARNING: use with care, if supplied, object options must match with user supplied options.
family response type (see above). Default is gaussian.
alpha.level level, such that quantile $\tau = (1 - \alpha\text{level})$. Default is 0.05.
M number of Monte Carlo Simulations to estimate the distribution $\Lambda$. Default is 1000.
qut.standardize standardize matrix X with a quantile-based standardization. Default is TRUE. It is not used for sqrt-lasso.
intercept should intercept(s) be fitted (default=TRUE) or set to zero (FALSE).
offset a vector of length n that is included in the linear predictor. Useful for the poisson family (e.g. log of exposure time), or for refining a model by starting at a current fit. Default is NULL.
bootstrap set TRUE if it is desired to bootstrap matrix X when computing the Quantile Universal Threshold (Random scenario). Default is TRUE.
sigma standard deviation of the Gaussian errors. Used only if family=gaussian. When sigma = 'qut', it is estimated based on the Quantile Universal Threshold (default if n <= 2p); when sigma = 'rcv', it is estimated using Refitted Cross Validation in Fan et al. 2012; and when sigma = 'cv', it is estimated using cross validation as in Reid et al. 2013. If sigma is a positive real number, then that value is used for the standard deviation. If n>p and sigma=’ols’ it is estimated using the ordinary least squares estimator (default if n>2p)
beta0 coefficients of the unpenalized covariates for generating the null data for the Quantile Universal Threshold. When is 'iterglm' (Default) or 'iter', it is estimated using one step iteration of the entire procedure with maximum likelihood estimation or the lasso estimation, respectively. If 'noiter' then it is estimated without iterating. If it is desired to set beta0 in advance, then it should be a vector of size the number of unpenalized covariates including the intercept if intercept=TRUE, in the same order. If there are not unpenalized covariates and intercept=TRUE, then it must be a real number.
estimator  type of estimation of sigma when sigma = 'qut'. It can be equal to 'unbiased' (standard unbiased formula), or 'mle' (maximum likelihood formula).

type  algorithm for solving the optimization problem. It can be lars (type='lars') or glmnet (type='glmnet') for GLM-lasso, or flare (type='flare') for Square-root lasso. For GLM-lasso, if family is not gaussian, penalty.factor is different from default, or offset different from NULL, glmnet will be always used. Default is 'glmnet'.

lambda.seq  preset lambda sequence when type = 'glmnet'. If lambda.seq<2 the sequence of lambdas goes decreasing from lambda.max to lambda.qut. If lambda.seq= 0, lambda sequence is equispaced. If lambda.seq= 1, lambda sequence is equispaced in the log scale. Use lambda.seq=2 for glmnet default options. Default is 0.

penalty.factor  separate penalty factors can be applied to each coefficient. This is a number that multiplies lambda to allow differential shrinkage. Can be 0 for some variables, which implies no shrinkage, and that variable is always included in the model. Default is 1 for all variables (and implicitly infinity for variables listed in exclude). Note: the penalty factors are internally rescaled to sum to n, and the lambda sequence will reflect this change.

lambda.min.ratio  smallest value for lambda, as a fraction of lambda.max. As in glmnet.

nlambda  the number of lambda. As in glmnet. Default is 100.

lambda  a user supplied lambda sequence. As in glmnet. Not used when type='flare'.

...  glmnet or lars options.

Value

lambda  value of the Quantile Universal Threshold.

fit  object fitted by glmnet or lars.

beta  coefficients obtained with the Quantile Universal Threshold.

betaglm  coefficients obtained fitting GLM with the non zero coefficients in beta.

beta0  estimated value of the intercept when family is not gaussian.

family  response type

sigma  standard deviation estimate of the errors (when family=gaussian)

scale.factor  scale factor used for standardizing X.

Author(s)

Jairo Diaz Rodriguez

References

riboflavin

See Also

lambdaqut

Examples

```r
set.seed(1234)
X = matrix(rnorm(50*500),50,500)
beta = c(rep(10,5),rep(0,500-5))
y = X %*% beta + rnorm(50)

outqut = qut(y, X, type = 'glmnet', family = 'gaussian', sigma = 1) # Fitting with qut
betaqut = outqut$beta[-1]

outcv = cv.glmnet(X, y, family = 'gaussian') # fitting with Cross-Validation
betacv = coef(outcv$glmnet.fit, s = outcv$lambda.min)[-1]

results = rbind(c(sum(betaqut[1:5] != 0), sum(betaqut[-(1:5)] != 0)),
                c(sum(betacv[1:5] != 0), sum(betacv[-(1:5)] != 0))

colnames(results) = c('True Positive', 'False Positive')
rownames(results) = c('qut', 'cv')

print(results)
```

riboflavin

*Riboflavin data set from Buhlmann et al. (2013)*

Description

Dataset of riboflavin production by Bacillus subtilis containing n = 71 observations of p = 4088 predictors (gene expressions) and a one-dimensional response (riboflavin production)

Usage

data(riboflavin)

Format

A data frame with 71 observations on the following 2 variables.

- **y** a numeric vector
- **x** a matrix with 4088 columns

References

Examples

```r
data(riboflavin)
```

**Description**

Estimation of \( \sigma \) using a two layer estimation scheme as in Refitted Cross Validation, by performing variable selection with the Quantile Universal Threshold, and obtaining the two estimations of \( \sigma \) with the ordinary least squares estimator.

**Usage**

```r
sigmaqut(y, X, estimator = "unbiased", intercept = TRUE,
alpha.level = "default", M = 1000, qut.standardize = TRUE,
penalty.factor = rep(1, p), offset = NULL, ...)
```

**Arguments**

- `y`: response variable. Quantitative for family=gaussian, or family=poisson (non-negative counts). For family=binomial should be a factor with two levels.
- `X`: input matrix, of dimension n x p; each row is an observation vector.
- `estimator`: type of estimation of sigma when `sigma` = 'qut'. It can be equal to 'unbiased' (standard unbiased formula), or 'mle' (maximum likelihood formula).
- `intercept`: should intercept(s) be fitted (default=TRUE) or set to zero (FALSE).
- `alpha.level`: level, such that quantile \( \tau = (1 - \alpha.level)/\gamma \). Default is \( 1/(\sqrt{\pi \log(p)}) \).
- `M`: number of Monte Carlo Simulations to estimate the distribution \( \Lambda \). Default is 1000.
- `qut.standardize`: standardize matrix X with a quantile-based standardization. Default is TRUE.
- `penalty.factor`: separate penalty factors can be applied to each coefficient. As in qut.
- `offset`: a vector of length n that is included in the linear predictor. As in qut.
- `...`: other glmnet options.

**Value**

Estimator of \( \sigma \)

**Note**

`lambdaqut.qut`

**Author(s)**

Jairo Diaz
**Description**

Variance estimation using refitted cross-validation in ultrahigh dimensional regression.

**Usage**

```r
sigmarcv(y, X, cv = FALSE, fit = NA, intercept = TRUE)
```

**Arguments**

- `y`: response variable. Quantitative for `family=gaussian`, or `family=poisson` (non-negative counts). For `family=binomial` should be a factor with two levels.
- `X`: input matrix, of dimension n x p; each row is an observation vector.
- `cv`: when `FALSE`, variance is estimated using Refitted Cross Validation in Fan et al. 2012; and when `TRUE`, it is estimated using cross validation as in Reid et al. 2013. Default is `FALSE`.
- `fit`: A user supplied `glmnet` or `lars` object. Typical usage is to leave it empty so that the program computes the regularization path using the algorithm selected in `type`. WARNING: use with care, if supplied, object options must match with user supplied options.
- `intercept`: should intercept(s) be fitted (default=TRUE) or set to zero (FALSE).

**Value**

Estimator of \( \sigma \)

**Author(s)**

Jianqing Fan, Shaojun Guo. Modified by Jairo Diaz.

**References**

Zero thresholding function

Description

Obtains the value of the minimum regularization parameter that sets all coefficients to zero for different types of thresholding tests.

Usage

```
ztf(y,Xdata, family=gaussian, A=ncol(Xdata), cc=NA, intercept=TRUE,
group.sizes=rep(1,ncol(Xdata)), LAD=FALSE, outrescale=NA, composite=TRUE, alpha=0,
M=min(1.e4, max(1000,1.e10/nrow(Xdata)/ncol(Xdata))))
```

Arguments

- `y`: response variable. Quantitative for `family=gaussian`, or `family=poisson` (non-negative counts). For `family=binomial` should be a factor with two levels.
- `Xdata`: input matrix, of dimension n x p; each row is an observation vector.
- `family`: response type (see above). Default is `gaussian`.
- `A`: if `A` is a matrix it tests $A \beta = c$. If `A` is a vector, then it gives the indexes of the parameters to be tested. Used if `family=gaussian`. Default is to test $\beta=0$, so $A=\text{ncol}(X)$.
- `cc`: vector $c$
- `intercept`: should intercept(s) be fitted (default=TRUE) or set to zero (FALSE).
- `group.sizes`: the vector of group sizes for affine group lasso. The number of elements is $L$ and sum(group.sizes) should be equal to $P$. If $L=\text{P}$, then the lasso test is employed, otherwise group lasso. Default is no groups, so $\text{rep}(1,\text{ncol}(X))$.
- `LAD`: set TRUE if LAD lasso test. Default is FALSE
- `outrescale`: object containing all variables corresponding to the rescaling and test options. If not provided, this is calculated automatically with function `processX`. Default is NA.
- `composite`: set TRUE if composite test (O & +). Default is TRUE
- `alpha`: alpha for quantile rescaling; if alpha=0, then no rescaling.
- `M`: number of Monte Carlo Simulations to estimate the distribution $\Lambda$.

Value

value of the minimum regularization parameter that sets all coefficients to zero

Author(s)

Sylvain Sardy and Jairo Diaz
Examples

# Test H0: beta=0
P=200
N=20
s=1
A=P
X=matrix(rnorm(N*P),N,P)
M=100 #Leave the default or select higher value for better level.
#when H0 is not rejected
beta_scal=0
beta=c(rep(beta_scal, s), rep(0, P-s))
y=X%*%beta+rnorm(N)
zerolambda=ztf(y,X,M=M)
print(zerolambda)

#when H0 is rejected
beta_scal=10
beta=c(rep(beta_scal, s), rep(0, P-s))
y=X%*%beta+rnorm(N)
zerolambda=ztf(y,X,M=M)
print(zerolambda)
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