Package 'QuaCP'

May 24, 2025

Title Change-plane Analysis in Functional Response Quantile Regression

Version 0.1.0

Author Xin Guan [aut],
Yiyuan Li [aut,cre],
Xu Liu [aut],
Jinhong You [aut]

Maintainer Yiyuan Li <liyiyuan@stu.sufe.edu.cn>

Description A Package of ``Change-plane Analysis in Functional Response Quantile Regression". In the paper, we consider a change-plane model within the framework of functional response quantile regression, capable of identifying and testing subgroups in non-Gaussian functional responses with scalar predictors. The alternating direction method of multipliers algorithm is designed to estimate the function coefficients and grouping parameters in the proposed model, thereby dividing the population into different subgroups. To further test the existence of subgroups, we develop a weighted average of the squared score test statistic, which has a closed form and reduces computational burden.

License GPL (>=2)

Encoding UTF-8

Roxygen list(markdown = TRUE)

RoxygenNote 7.3.2

Depends R (>= 3.5.0)

Imports MASS, VGAM, Matrix, stats

LazyData true

R topics documented:

gendata *Generate Simulated Data for Functional Change-plane Quantile Regression Model.*

Description

Generates simulated datasets for functional change-plane quantile regression models. This function creates synthetic data with customizable parameters including sample size, covariate dimensions, and error distributions.

Usage

```
gendata(seed, n, m, p, d, q, param_kind, gamma, is_sig, err_kind, tau, istest=0, ch=1)
```

Arguments

seed	Random seed for reproducibility (integer).
n	Sample size (positive integer).
m	Number of observation points in functional domain (positive integer).
p	Dimension of covariates x, the second colum is 1 (positive integer, here p must be less than 6).
d	Dimension of covariates sub_x which the subset of x (positive integer).
q	Dimension of grouping variable (positive integer).
param_kind	Kind of slope function(There are 1 to 5 function options available, and each number contains one function).
gamma	Grouping parameter vector (length q-1).
is_sig	Threshold effect activation flag (0=disable, 1=enable, default=0).
err_kind	Error distribution: "gaussian", "t3", "weibull" or "laplace" .
tau	Quantile level.
istest	Simulaton for estimation (0) or testing (1).
ch	Signal strength for testing.

Value

A list containing:

y	Function response matrix (n x m).
x	Scalar covariate matrix (n x p).
sub_x	Scalar covariate matrix, the subset of X (n x d).
z	Grouping variable (n x q).
beta	True slope functions of x.
deta	True slope functions of sub_x.

Examples

```
seed = 10086
n    = 200
m    = 30
p    = 3
q    = 2
d    = 2
tau  = 0.5
t_gamma    = c(-1, 1)
param_kind = c(3,1,2,4,5)
issig      = 1
istest     = 0
theta      = c(-0.5, 0.5)

sim_data = gendata(seed, n, m, p, d, q,
                   param_kind, t_gamma, issig, 't3', tau, istest)

# Inspect structure
str(sim_data)
```

`qfcp` *Functional Change-plane Quantile Regression via ADMM*

Description

Implements Alternating Direction Method of Multipliers (ADMM) for functional change-plane quantile regression models. This method handles quantile regression with subgroup structures via RKHS.

Usage

```
qfcp(x, y, z, sub_x, m, kernel_sigma, sigma, lambda, tau)
```

Arguments

`x`	Design matrix (n x p) of scalar covariates.
`y`	Functional response matrix (n x m).
`z`	Grouping variable matrix (n x q), second column is intercept.
`sub_x`	Threshold covariate subset matrix (n x d).
`m`	Number of functional domain points.
`kernel_sigma`	Bandwidth parameter for Gaussian kernel construction.
`sigma`	ADMM penalty parameter.
`lambda`	Regularization parameter.
`tau`	Quantile level in (0,1).

Value

`gamma`	Estimated subgroup parameters (length q-1).
`d`	Coefficient functions (m(p+d) x 1 vector).
`w`	Dual variables matrix (n x m).

References

Guan X, Li Y, Liu X, You J (2025). "Change-plane analysis in functional response quantile regression." *arXiv preprint* arXiv:2503.07332.

Boyd S, Parikh N, Chu E, Peleato B, Eckstein J (2011). "Distributed Optimization and Statistical Learning via the Alternating Direction Method of Multipliers." *Foundations and Trends in Machine Learning* 3(1):1-122.

Yuan M, Cai TT (2010). "A Reproducing Kernel Hilbert Space Approach to Functional Linear Regression." *Annals of Statistics* 38(6):3412-3444.

Zhang Z, Wang X, Kong L, Zhu H (2022). "High-Dimensional Spatial Quantile Function-on-Scalar Regression." *Journal of the American Statistical Association* 117:1563-1578.

Examples

```
seed = 10086
n    = 200
m    = 30
p    = 3
q    = 2
d    = 2
tau  = 0.5
t_gamma    = c(-1, 1)
param_kind = c(3,1,2,4,5)
issig      = 1
istest     = 0
theta      = c(-0.5, 0.5)

data = gendata(seed, n, m, p, d, q,
                  param_kind, t_gamma, issig, 't3', tau, istest)

fit1 <- qfcp(data$x, data$y, data$z, data$sub_x, m, kernel_sigma=0.5,
             sigma=1, lambda=0.01, tau=0.5)
```

`qfcp0` *Functional Change-plane Quantile Regression via ADMM*

Description

Implements Alternating Direction Method of Multipliers (ADMM) for functional quantile regression models vis RKHS.

Usage

```
qfcp0(x, y, m, kernel_sigma, sigma, lambda, tau)
```

Arguments

`x`	Design matrix (n x p) of scalar covariates.
`y`	Functional response matrix (n x m).
`m`	Number of functional domain points.

kernel_sigma	Bandwidth parameter for Gaussian kernel construction.
sigma	ADMM penalty parameter.
lambda	Regularization parameter.
tau	Quantile level in (0,1).

Value

d	Baseline coefficient functions (mp x 1 vector).
res	Residual matrix (n x m).
haty	Fitted values (n x m).
Df	Effective degrees of freedom.

References

Guan X, Li Y, Liu X, You J (2025). "Change-plane analysis in functional response quantile regression." *arXiv preprint* arXiv:2503.07332.

Boyd S, Parikh N, Chu E, Peleato B, Eckstein J (2011). "Distributed Optimization and Statistical Learning via the Alternating Direction Method of Multipliers." *Foundations and Trends in Machine Learning* 3(1):1-122.

Yuan M, Cai TT (2010). "A Reproducing Kernel Hilbert Space Approach to Functional Linear Regression." *Annals of Statistics* 38(6):3412-3444.

Zhang Z, Wang X, Kong L, Zhu H (2022). "High-Dimensional Spatial Quantile Function-on-Scalar Regression." *Journal of the American Statistical Association* 117:1563-1578.

Examples

```
seed = 10086
n    = 200
m    = 30
p    = 3
q    = 2
d    = 2
tau  = 0.5
t_gamma    = c(-1, 1)
param_kind = c(3,1,2,4,5)
issig      = 0
istest     = 0
theta      = c(-0.5, 0.5)

data = gendata(seed, n, m, p, d, q,
                  param_kind, t_gamma, issig, 't3', tau, istest)

fit0 <- qfcp0(data$x, data$y, m, kernel_sigma=0.5,
             sigma=1, lambda=0.01, tau=0.5)
```

wast_pval *Subgroup Testing for Functional Change-plane Quantile Regression via WAST Method*

Description

A test method based on Weighted Squared Score Statistic (WAST) is proposed to detect the subgroup effect in functional quantile regression. This method significantly reduces the computational complexity through the closed-loop test statistic formula.

Usage

```
wast_pval(x, y, z, m, tx, tau = 0.5, B = 1000,
     kernel_sigma = 0.2)
```

Arguments

x	Design matrix of scalar covariates
y	Functional response matrix
z	Grouping variable matrix
m	Functional domain grid points vector.
tx	Covariate matrix for testing
tau	Quantile level in (0,1), default=0.5 (median)
B	Number of bootstrap samples, default=500
kernel_sigma	Bandwidth for Gaussian kernel smoothing (>0), default=0.2

Value

p_value	P-value for the hypothesis test

References

Guan X, Li Y, Liu X, You J (2025). "Change-plane analysis in functional response quantile regression." *arXiv preprint* arXiv:2503.07332.

Liu X, Huang J, Zhou Y, Zhang F, Ren P (2024). "Efficient subgroup testing in change-plane models." *arXiv preprint* arXiv:2408.00602.

Examples

```
seed = 10086
n    = 200
m    = 30
p    = 3
q    = 2
d    = 2
tau  = 0.5
t_gamma    = c(-1, 1)
param_kind = c(3,1,2,4,5)
issig      = 0
istest     = 1
```

```
ch         = 1
theta      = c(-0.5, 0.5)

data = gendata(seed, n, m, p, d, q,
                 param_kind, t_gamma, issig, 't3', tau, istest, ch)

result <- wast_pval(data$x, data$y, data$z, m, data$sub_x,
              tau = 0.5, B = 500,
              kernel_sigma = 0.2)
```

Index