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Description Performs causal functional mediation analysis (CFMA) for functional treatment, functional mediator, and functional outcome. This package includes two functional mediation model types: (1) a concurrent mediation model and (2) a historical influence mediation model. See Zhao et al. (2018), Functional Mediation Analysis with an Application to Functional Magnetic Resonance Imaging Data, <arXiv:1805.06923> for details.

License GPL (>=2)

Depends R (>= 2.10)

Repository <https://zhaoyi1026.r-universe.dev>

RemoteUrl <https://github.com/zhaoyi1026/cfma>

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`cfma-package`*Causal Functional Mediation Analysis*

Description

cfma package performs causal functional mediation analysis (CFMA) for functional treatment, functional mediator, and functional outcome. This package includes two functional mediation model type: (1) a concurrent mediation model and (2) a historical influence mediation model.

Details

Package: cfma
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`env.concurrent`*Simulated data from the concurrent mediation model*

Description

"env.concurrent" is an R environment containing the data generated from a concurrent mediation model.

Usage

```
data("env.concurrent")
```

Format

An R environment

Z a $n \times T$ data matrix, treatment trajectory of n subjects for T time points.

M a $n \times T$ data matrix, mediator trajectory of n subjects for T time points.

Y a $n \times T$ data matrix, outcome trajectory of n subjects for T time points.

α a length T vector model coefficient.

β a length T vector model coefficient.

γ a length T vector model coefficient.

Details

The data was generated from the concurrent mediation model

$$M(t) = Z(t)\alpha(t) + \epsilon_1(t),$$

$$R(t) = Z(t)\gamma(t) + M(t)\beta(t) + \epsilon_2(t).$$

$Z(t)$ is the convolution of hemodynamic response function (HRF) and event onsets.

Examples

```
data(env.concurrent)
Z<-get("Z",env.concurrent)
M<-get("M",env.concurrent)
Y<-get("Y",env.concurrent)
```

env.historical

Simulated data from the historical influence mediation model

Description

"env.historical" is an R environment containing the data generated from a historical influence mediation model.

Usage

```
data("env.historical")
```

Format

An R environment

Z a $n \times T$ data matrix, treatment trajectory of n subjects for T time points.

M a $n \times T$ data matrix, mediator trajectory of n subjects for T time points.

Y a $n \times T$ data matrix, outcome trajectory of n subjects for T time points.

α a $T \times T$ matrix model coefficient.

β a $T \times T$ matrix model coefficient.

γ a $T \times T$ matrix model coefficient.

Details

The data was generated from the historical influence mediation model

$$M(t) = \int_{\Omega_t^1} Z(s)\alpha(s,t)ds + \epsilon_1(t),$$

$$Y(t) = \int_{\Omega_t^2} Z(s)\gamma(s,t)ds + \int_{\Omega_t^3} M(s)\beta(s,t)ds + \epsilon_2(t),$$

where $\alpha(s, t)$, $\beta(s, t)$, $\gamma(s, t)$ are coefficient curves; $\Omega_t^j = [(t - \delta_j) \vee 0, t]$ for $j = 1, 2, 3$. $Z(t)$ is the convolution of hemodynamic response function (HRF) and event onsets.

Examples

```
data(env.historical)
Z<-get("Z",env.historical)
M<-get("M",env.historical)
Y<-get("Y",env.historical)
```

FMA.concurrent

Functional mediation analysis under concurrent regression model

Description

This function performs functional mediation regression under the concurrent model with given tuning parameter.

Usage

```
FMA.concurrent(Z, M, Y, intercept = TRUE, basis = NULL, Ld2.basis = NULL,
  basis.type = c("fourier"), nbasis = 3, timeinv = c(0, 1), timegrids = NULL,
  lambda.m = 0.01, lambda.y = 0.01)
```

Arguments

Z	a data matrix. Z is the treatment trajectory in the mediation analysis. The number of rows is the number of subjects, and the number of columns is the number of measured time points.
M	a data matrix. M is the mediator trajectory in the mediation analysis. The number of rows is the number of subjects, and the number of columns is the number of measured time points.
Y	a data matrix. Y is the outcome trajectory in the mediation analysis. The number of rows is the number of subjects, and the number of columns is the number of measured time points.
intercept	a logic variable. Default is TRUE, an intercept term is included in the regression model.

basis	a data matrix. Basis function used in the functional data analysis. The number of columns is the number of basis function considered. If basis = NULL, Fourier basis functions will be generated.
Ld2.basis	a data matrix. The second derivative of the basis function. The number of columns is the number of basis function considered. If Ld2.basis = NULL, the second derivative of Fourier basis functions will be generated.
basis.type	a character of basis function type. Default is Fourier basis (basis.type = "fourier").
nbasis	an integer, the number of basis function included. If basis is provided, this argument will be ignored.
timeinv	a numeric vector of length two, the time interval considered in the analysis. Default is (0,1).
timegrids	a numeric vector of time grids of measurement. If timegrids = NULL, it is assumed the between measurement time interval is constant.
lambda.m	a numeric value of the tuning parameter in the mediator model.
lambda.y	a numeric value of the tuning parameter in the outcome model.

Details

The concurrent mediation model is

$$M(t) = Z(t)\alpha(t) + \epsilon_1(t),$$

$$Y(t) = Z(t)\gamma(t) + M(t)\beta(t) + \epsilon_2(t),$$

where $\alpha(t)$, $\beta(t)$, $\gamma(t)$ are coefficient curves. The model coefficient curves are estimated by minimizing the penalized L_2 -loss.

Value

basis	the basis functions used in the analysis.
M	a list of output for the mediator model coefficient: the estimated coefficient with respect to the basis function curve: the estimated coefficient curve fitted: the fitted value of M lambda: λ value
Y	a list of output for the outcome model coefficient: the estimated coefficient with respect to the basis function curve: the estimated coefficient curve fitted: the fitted value of Y lambda: λ value
IE	a list of output for the indirect effect comparing $Z_1(t) = 1$ versus $Z_0(t) = 0$ coefficients: the coefficient with respect to the basis function curve: the estimated causal curve
DE	a list of output for the direct effect comparing $Z_1(t) = 1$ versus $Z_0(t) = 0$ coefficients: the coefficient with respect to the basis function curve: the estimated causal curve

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 Brian Caffo, Johns Hopkins University, <bcaffo@gmail.com>

References

Zhao et al. (2017). *Functional Mediation Analysis with an Application to Functional Magnetic Resonance Imaging Data*. arXiv preprint arXiv:1805.06923.

Examples

```
#####
# Concurrent functional mediation model
data(env.concurrent)
Z<-get("Z",env.concurrent)
M<-get("M",env.concurrent)
Y<-get("Y",env.concurrent)

# consider Fourier basis
fit<-FMA.concurrent(Z,M,Y,intercept=FALSE,timeinv=c(0,300))

# estimate of alpha
plot(fit$M$curve[1,],type="l",lwd=5)
lines(get("alpha",env.concurrent),lty=2,lwd=2,col=2)

# estimate of gamma
plot(fit$Y$curve[1,],type="l",lwd=5)
lines(get("gamma",env.concurrent),lty=2,lwd=2,col=2)

# estimate of beta
plot(fit$Y$curve[2,],type="l",lwd=5)
lines(get("beta",env.concurrent),lty=2,lwd=2,col=2)

# estimate of causal curves
plot(fit$IE$curve,type="l",lwd=5)
plot(fit$DE$curve,type="l",lwd=5)
#####
```

FMA.concurrent.boot *Functional mediation analysis under concurrent regression model
with point-wise bootstrap confidence interval*

Description

This function performs functional mediation regression under the concurrent model with given tuning parameter. Point-wise confidence bands are obtained from bootstrap.

Usage

```
FMA.concurrent.boot(Z, M, Y, intercept = TRUE, basis = NULL, Ld2.basis = NULL,
  basis.type = c("fourier"), nbasis = 3, timeinv = c(0, 1), timegrids = NULL,
  lambda.m = 0.01, lambda.y = 0.01, sims = 1000, boot = TRUE,
  boot.ci.type = c("bca", "perc"), conf.level = 0.95, verbose = TRUE)
```

Arguments

Z	a data matrix. Z is the treatment trajectory in the mediation analysis. The number of rows is the number of subjects, and the number of columns is the number of measured time points.
M	a data matrix. M is the mediator trajectory in the mediation analysis. The number of rows is the number of subjects, and the number of columns is the number of measured time points.
Y	a data matrix. Y is the outcome trajectory in the mediation analysis. The number of rows is the number of subjects, and the number of columns is the number of measured time points.
intercept	a logic variable. Default is TRUE, an intercept term is included in the regression model.
basis	a data matrix. Basis function used in the functional data analysis. The number of columns is the number of basis function considered. If basis = NULL, Fourier basis functions will be generated.
Ld2.basis	a data matrix. The second derivative of the basis function. The number of columns is the number of basis function considered. If Ld2.basis = NULL, the second derivative of Fourier basis functions will be generated.
basis.type	a character of basis function type. Default is Fourier basis (basis.type = "fourier").
nbasis	an integer, the number of basis function included. If basis is provided, this argument will be ignored.
timeinv	a numeric vector of length two, the time interval considered in the analysis. Default is (0,1).
timegrids	a numeric vector of time grids of measurement. If timegrids = NULL, it is assumed the between measurement time interval is constant.
lambda.m	a numeric value of the tuning parameter in the mediator model.
lambda.y	a numeric value of the tuning parameter in the outcome model.
sims	an integer indicating the number of simulations for inference.
boot	a logical value, indicating whether or not bootstrap should be used. Default is TRUE.
boot.ci.type	a character of confidence interval method. boot.ci.type = "bca" bias corrected confidence interval; boot.ci.type = "perc" percentile confidence interval.
conf.level	a number of significance level. Default is 0.95.
verbose	a logical value, indicating whether print out bootstrap replications.

Details

The concurrent mediation model is

$$M(t) = Z(t)\alpha(t) + \epsilon_1(t),$$

$$Y(t) = Z(t)\gamma(t) + M(t)\beta(t) + \epsilon_2(t),$$

where $\alpha(t)$, $\beta(t)$, $\gamma(t)$ are coefficient curves. The model coefficient curves are estimated by minimizing the penalized L_2 -loss.

Value

alpha	a list of output for α estimate coefficients: the result of the coefficient estimates corresponding to the basis function curve: the point-wise estimate of the coefficient curve
gamma	: a list of output for γ estimate coefficients: the result of the coefficient estimates corresponding to the basis function curve: the point-wise estimate of the coefficient curve
beta	a list of output for β estimate coefficients: the result of the coefficient estimates corresponding to the basis function curve: the point-wise estimate of the coefficient curve
IE	a list of output for indirect effect estimate coefficients: the result of the coefficient estimates corresponding to the basis function curve: the point-wise estimate of the coefficient curve
DE	a list of output for direct effect estimate coefficients: the result of the coefficient estimates corresponding to the basis function curve: the point-wise estimate of the coefficient curve

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References

Zhao et al. (2017). *Functional Mediation Analysis with an Application to Functional Magnetic Resonance Imaging Data*. arXiv preprint arXiv:1805.06923.

Examples

```
#####
# Concurrent functional mediation model
data(env.concurrent)
Z<-get("Z",env.concurrent)
M<-get("M",env.concurrent)
Y<-get("Y",env.concurrent)

# consider Fourier basis
fit.boot<-FMA.concurrent.boot(Z,M,Y,intercept=FALSE,timeinv=c(0,300))

#####
```

FMA.concurrent.CV *Functional mediation analysis under concurrent regression model*

Description

This function performs functional mediation regression under the concurrent model. Tuning parameter is chosen based on cross-validation.

Usage

```
FMA.concurrent.CV(Z, M, Y, intercept = TRUE, basis = NULL, Ld2.basis = NULL,
  basis.type = c("fourier"), nbasis = 3, timeinv = c(0, 1), timegrids = NULL,
  lambda = NULL, nolds = 5)
```

Arguments

Z	a data matrix. Z is the treatment trajectory in the mediation analysis. The number of rows is the number of subjects, and the number of columns is the number of measured time points.
M	a data matrix. M is the mediator trajectory in the mediation analysis. The number of rows is the number of subjects, and the number of columns is the number of measured time points.
Y	a data matrix. Y is the outcome trajectory in the mediation analysis. The number of rows is the number of subjects, and the number of columns is the number of measured time points.
intercept	a logic variable. Default is TRUE, an intercept term is included in the regression model.
basis	a data matrix. Basis function used in the functional data analysis. The number of columns is the number of basis function considered. If basis = NULL, Fourier basis functions will be generated.
Ld2.basis	a data matrix. The second derivative of the basis function. The number of columns is the number of basis function considered. If Ld2.basis = NULL, the second derivative of Fourier basis functions will be generated.

basis.type	a character of basis function type. Default is Fourier basis (basis.type = "fourier").
nbasis	an integer, the number of basis function included. If basis is provided, this argument will be ignored.
timeinv	a numeric vector of length two, the time interval considered in the analysis. Default is (0,1).
timegrids	a numeric vector of time grids of measurement. If timegrids = NULL, it is assumed the between measurement time interval is constant.
lambda	a numeric vector of tuning parameter values.
nfolds	a number gives the number of folds in cross-validation.

Details

The concurrent mediation model is

$$M(t) = Z(t)\alpha(t) + \epsilon_1(t),$$

$$Y(t) = Z(t)\gamma(t) + M(t)\beta(t) + \epsilon_2(t),$$

where $\alpha(t)$, $\beta(t)$, $\gamma(t)$ are coefficient curves. The model coefficient curves are estimated by minimizing the penalized L_2 -loss. Tuning parameter λ controls the smoothness of the estimated curves, and is chosen by cross-validation.

Value

basis	the basis functions used in the analysis.
M	a list of output for the mediator model coefficient: the estimated coefficient with respect to the basis function curve: the estimated coefficient curve fitted: the fitted value of M lambda: the chosen λ value
Y	a list of output for the outcome model coefficient: the estimated coefficient with respect to the basis function curve: the estimated coefficient curve fitted: the fitted value of Y lambda: the chosen λ value
IE	a list of output for the indirect effect comparing $Z_1(t) = 1$ versus $Z_0(t) = 0$ coefficients: the coefficient with respect to the basis function curve: the estimated causal curve
DE	a list of output for the direct effect comparing $Z_1(t) = 1$ versus $Z_0(t) = 0$ coefficients: the coefficient with respect to the basis function curve: the estimated causal curve

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References

Zhao et al. (2017). *Functional Mediation Analysis with an Application to Functional Magnetic Resonance Imaging Data*. arXiv preprint arXiv:1805.06923.

Examples

```
#####
# Concurrent functional mediation model
data(env.concurrent)
Z<-get("Z",env.concurrent)
M<-get("M",env.concurrent)
Y<-get("Y",env.concurrent)

## Not run:
# consider Fourier basis
fit<-FMA.concurrent.CV(Z,M,Y,intercept=FALSE,timeinv=c(0,300))

# estimate of alpha
plot(fit$M$curve[1,],type="l",lwd=5)
lines(get("alpha",env.concurrent),lty=2,lwd=2,col=2)

# estimate of gamma
plot(fit$Y$curve[1,],type="l",lwd=5)
lines(get("gamma",env.concurrent),lty=2,lwd=2,col=2)

# estimate of beta
plot(fit$Y$curve[2,],type="l",lwd=5)
lines(get("beta",env.concurrent),lty=2,lwd=2,col=2)

# estimate of causal curves
plot(fit$IE$curve,type="l",lwd=5)
plot(fit$DE$curve,type="l",lwd=5)

## End(Not run)
#####
```

FMA.historical

Functional mediation analysis under historical influence model

Description

This function performs functional mediation regression under the historical influence model with given tuning parameter.

Usage

```
FMA.historical(Z, M, Y, delta.grid1 = 1, delta.grid2 = 1, delta.grid3 = 1,
  intercept = TRUE, basis1 = NULL, Ld2.basis1 = NULL, basis2 = NULL, Ld2.basis2 = NULL,
  basis.type = c("fourier"), nbasis1 = 3, nbasis2 = 3,
```

```
timeinv = c(0, 1), timegrids = NULL,
lambda1.m = 0.01, lambda2.m = 0.01, lambda1.y = 0.01, lambda2.y = 0.01)
```

Arguments

Z	a data matrix. Z is the treatment trajectory in the mediation analysis. The number of rows is the number of subjects, and the number of columns is the number of measured time points.
M	a data matrix. M is the mediator trajectory in the mediation analysis. The number of rows is the number of subjects, and the number of columns is the number of measured time points.
Y	a data matrix. Y is the outcome trajectory in the mediation analysis. The number of rows is the number of subjects, and the number of columns is the number of measured time points.
delta.grid1	a number indicates the width of treatment-mediator time interval in the mediator model.
delta.grid2	a number indicates the width of treatment-outcome time interval in the outcome model.
delta.grid3	a number indicates the width of mediator-outcome time interval in the outcome model.
intercept	a logic variable. Default is TRUE, an intercept term is included in the regression model.
basis1	a data matrix. Basis function on the s domain used in the functional data analysis. The number of columns is the number of basis function considered. If basis = NULL, Fourier basis functions will be generated.
Ld2.basis1	a data matrix. The second derivative of the basis function on the s domain. The number of columns is the number of basis function considered. If Ld2.basis = NULL, the second derivative of Fourier basis functions will be generated.
basis2	a data matrix. Basis function on the t domain used in the functional data analysis. The number of columns is the number of basis function considered. If basis = NULL, Fourier basis functions will be generated.
Ld2.basis2	a data matrix. The second derivative of the basis function on the t domain. The number of columns is the number of basis function considered. If Ld2.basis = NULL, the second derivative of Fourier basis functions will be generated.
basis.type	a character of basis function type. Default is Fourier basis (basis.type = "fourier").
nbasis1	an integer, the number of basis function on the s domain included. If basis1 is provided, this argument will be ignored.
nbasis2	an integer, the number of basis function on the t domain included. If basis2 is provided, this argument will be ignored.
timeinv	a numeric vector of length two, the time interval considered in the analysis. Default is (0,1).
timegrids	a numeric vector of time grids of measurement. If timegrids = NULL, it is assumed the between measurement time interval is constant.

lambda1.m	a numeric vector of tuning parameter values on the s domain in the mediator model.
lambda2.m	a numeric vector of tuning parameter values on the t domain in the mediator model.
lambda1.y	a numeric vector of tuning parameter values on the s domain in the outcome model.
lambda2.y	a numeric vector of tuning parameter values on the t domain in the outcome model.

Details

The historical influence mediation model is

$$M(t) = \int_{\Omega_t^1} Z(s)\alpha(s,t)ds + \epsilon_1(t),$$

$$Y(t) = \int_{\Omega_t^2} Z(s)\gamma(s,t)ds + \int_{\Omega_t^3} M(s)\beta(s,t)ds + \epsilon_2(t),$$

where $\alpha(s,t)$, $\beta(s,t)$, $\gamma(s,t)$ are coefficient curves; $\Omega_t^j = [(t - \delta_j) \vee 0, t]$ for $j = 1, 2, 3$. The model coefficient curves are estimated by minimizing the penalized L_2 -loss.

Value

basis1	the basis functions on the s domain used in the analysis.
basis2	the basis functions on the t domain used in the analysis.
M	a list of output for the mediator model coefficient: the estimated coefficient with respect to the basis function curve: the estimated coefficient curve fitted: the fitted value of M lambda1: the λ value on the s domain lambda2: the λ value on the t domain
Y	a list of output for the outcome model coefficient: the estimated coefficient with respect to the basis function curve: the estimated coefficient curve fitted: the fitted value of Y lambda1: the λ value on the s domain lambda2: the λ value on the t domain
IE	a list of output for the indirect effect comparing $Z_1(t) = 1$ versus $Z_0(t) = 0$ curve: the estimated causal curve
DE	a list of output for the direct effect comparing $Z_1(t) = 1$ versus $Z_0(t) = 0$ curve: the estimated causal curve

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References

Zhao et al. (2017). *Functional Mediation Analysis with an Application to Functional Magnetic Resonance Imaging Data*. arXiv preprint arXiv:1805.06923.

Examples

```
#####
# Historical influence functional mediation model
data(env.historical)
Z<-get("Z",env.historical)
M<-get("M",env.historical)
Y<-get("Y",env.historical)

# consider Fourier basis
fit<-FMA.historical(Z,M,Y,delta.grid1=3,delta.grid2=3,delta.grid3=3,
  intercept=FALSE,timeinv=c(0,300))

# estimate of causal curves
plot(fit$IE$curve,type="l",lwd=5)
plot(fit$DE$curve,type="l",lwd=5)
#####
```

FMA.historical.boot *Functional mediation analysis under historical influence regression model with point-wise bootstrap confidence interval*

Description

This function performs functional mediation regression under the historical influence model with given tuning parameter. Point-wise confidence bands are obtained from bootstrap.

Usage

```
FMA.historical.boot(Z, M, Y, delta.grid1 = 1, delta.grid2 = 1, delta.grid3 = 1,
  intercept = TRUE, basis1 = NULL, Ld2.basis1 = NULL, basis2 = NULL, Ld2.basis2 = NULL,
  basis.type = c("fourier"), nbasis1 = 3, nbasis2 = 3,
  timeinv = c(0, 1), timegrids = NULL,
  lambda1.m = 0.01, lambda2.m = 0.01, lambda1.y = 0.01, lambda2.y = 0.01,
  sims = 1000, boot = TRUE, boot.ci.type = c("bca", "perc"),
  conf.level = 0.95, verbose = TRUE)
```

Arguments

Z	a data matrix. Z is the treatment trajectory in the mediation analysis. The number of rows is the number of subjects, and the number of columns is the number of measured time points.
M	a data matrix. M is the mediator trajectory in the mediation analysis. The number of rows is the number of subjects, and the number of columns is the number of measured time points.
Y	a data matrix. Y is the outcome trajectory in the mediation analysis. The number of rows is the number of subjects, and the number of columns is the number of measured time points.
delta.grid1	a number indicates the width of treatment-mediator time interval in the mediator model.
delta.grid2	a number indicates the width of treatment-outcome time interval in the outcome model.
delta.grid3	a number indicates the width of mediator-outcome time interval in the outcome model.
intercept	a logic variable. Default is TRUE, an intercept term is included in the regression model.
basis1	a data matrix. Basis function on the s domain used in the functional data analysis. The number of columns is the number of basis function considered. If <code>basis = NULL</code> , Fourier basis functions will be generated.
Ld2.basis1	a data matrix. The second derivative of the basis function on the s domain. The number of columns is the number of basis function considered. If <code>Ld2.basis = NULL</code> , the second derivative of Fourier basis functions will be generated.
basis2	a data matrix. Basis function on the t domain used in the functional data analysis. The number of columns is the number of basis function considered. If <code>basis = NULL</code> , Fourier basis functions will be generated.
Ld2.basis2	a data matrix. The second derivative of the basis function on the t domain. The number of columns is the number of basis function considered. If <code>Ld2.basis = NULL</code> , the second derivative of Fourier basis functions will be generated.
basis.type	a character of basis function type. Default is Fourier basis (<code>basis.type = "fourier"</code>).
nbasis1	an integer, the number of basis function on the s domain included. If <code>basis1</code> is provided, this argument will be ignored.
nbasis2	an integer, the number of basis function on the t domain included. If <code>basis2</code> is provided, this argument will be ignored.
timeinv	a numeric vector of length two, the time interval considered in the analysis. Default is (0,1).
timegrids	a numeric vector of time grids of measurement. If <code>timegrids = NULL</code> , it is assumed the between measurement time interval is constant.
lambda1.m	a numeric vector of tuning parameter values on the s domain in the mediator model.
lambda2.m	a numeric vector of tuning parameter values on the t domain in the mediator model.

lambda1.y	a numeric vector of tuning parameter values on the s domain in the outcome model.
lambda2.y	a numeric vector of tuning parameter values on the t domain in the outcome model.
sims	an integer indicating the number of simulations for inference.
boot	a logical value, indicating whether or not bootstrap should be used. Default is TRUE.
boot.ci.type	a character of confidence interval method. boot.ci.type = "bca" bias corrected confidence interval; boot.ci.type = "perc" percentile confidence interval.
conf.level	a number of significance level. Default is 0.95.
verbose	a logical value, indicating whether print out bootstrap replications.

Details

The historical influence mediation model is

$$M(t) = \int_{\Omega_t^1} Z(s)\alpha(s,t)ds + \epsilon_1(t),$$

$$Y(t) = \int_{\Omega_t^2} Z(s)\gamma(s,t)ds + \int_{\Omega_t^3} M(s)\beta(s,t)ds + \epsilon_2(t),$$

where $\alpha(s,t)$, $\beta(s,t)$, $\gamma(s,t)$ are coefficient curves; $\Omega_t^j = [(t - \delta_j) \vee 0, t]$ for $j = 1, 2, 3$. The model coefficient curves are estimated by minimizing the penalized L_2 -loss.

Value

alpha	a list of output for α estimate coefficients: the result of the coefficient estimates corresponding to the basis function curve: the point-wise estimate of the coefficient curve
gamma	a list of output for γ estimate coefficients: the result of the coefficient estimates corresponding to the basis function curve: the point-wise estimate of the coefficient curve
beta	a list of output for β estimate coefficients: the result of the coefficient estimates corresponding to the basis function curve: the point-wise estimate of the coefficient curve
IE	a list of output for indirect effect estimate curve: the point-wise estimate of the coefficient curve
DE	a list of output for direct effect estimate curve: the point-wise estimate of the coefficient curve

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References

Zhao et al. (2017). *Functional Mediation Analysis with an Application to Functional Magnetic Resonance Imaging Data*. arXiv preprint arXiv:1805.06923.

Examples

```
#####
# Historical influence functional mediation model
data(env.historical)
Z<-get("Z",env.historical)
M<-get("M",env.historical)
Y<-get("Y",env.historical)

# consider Fourier basis
fit.boot<-FMA.historical.boot(Z,M,Y,delta.grid1=3,delta.grid2=3,delta.grid3=3,
  intercept=FALSE,timeinv=c(0,300))

#####
```

FMA.historical.CV *Functional mediation analysis under historical influence model*

Description

This function performs functional mediation regression under the historical influence model. Tuning parameter is chosen based on cross-validation.

Usage

```
FMA.historical.CV(Z, M, Y, delta.grid1 = 1, delta.grid2 = 1, delta.grid3 = 1,
  intercept = TRUE, basis1 = NULL, Ld2.basis1 = NULL, basis2 = NULL, Ld2.basis2 = NULL,
  basis.type = c("fourier"), nbasis1 = 3, nbasis2 = 3,
  timeinv = c(0, 1), timegrids = NULL, lambda1 = NULL, lambda2 = NULL, nfolds = 5)
```

Arguments

Z	a data matrix. Z is the treatment trajectory in the mediation analysis. The number of rows is the number of subjects, and the number of columns is the number of measured time points.
M	a data matrix. M is the mediator trajectory in the mediation analysis. The number of rows is the number of subjects, and the number of columns is the number of measured time points.
Y	a data matrix. Y is the outcome trajectory in the mediation analysis. The number of rows is the number of subjects, and the number of columns is the number of measured time points.
delta.grid1	a number indicates the width of treatment-mediator time interval in the mediator model.
delta.grid2	a number indicates the width of treatment-outcome time interval in the outcome model.
delta.grid3	a number indicates the width of mediator-outcome time interval in the outcome model.
intercept	a logic variable. Default is TRUE, an intercept term is included in the regression model.
basis1	a data matrix. Basis function on the s domain used in the functional data analysis. The number of columns is the number of basis function considered. If <code>basis = NULL</code> , Fourier basis functions will be generated.
Ld2.basis1	a data matrix. The second derivative of the basis function on the s domain. The number of columns is the number of basis function considered. If <code>Ld2.basis = NULL</code> , the second derivative of Fourier basis functions will be generated.
basis2	a data matrix. Basis function on the t domain used in the functional data analysis. The number of columns is the number of basis function considered. If <code>basis = NULL</code> , Fourier basis functions will be generated.
Ld2.basis2	a data matrix. The second derivative of the basis function on the t domain. The number of columns is the number of basis function considered. If <code>Ld2.basis = NULL</code> , the second derivative of Fourier basis functions will be generated.
basis.type	a character of basis function type. Default is Fourier basis (<code>basis.type = "fourier"</code>).
nbasis1	an integer, the number of basis function on the s domain included. If <code>basis1</code> is provided, this argument will be ignored.
nbasis2	an integer, the number of basis function on the t domain included. If <code>basis2</code> is provided, this argument will be ignored.
timeinv	a numeric vector of length two, the time interval considered in the analysis. Default is (0,1).
timegrids	a numeric vector of time grids of measurement. If <code>timegrids = NULL</code> , it is assumed the between measurement time interval is constant.
lambda1	a numeric vector of tuning parameter values on the s domain.
lambda2	a numeric vector of tuning parameter values on the t domain.
nfolds	a number gives the number of folds in cross-validation.

Details

The historical influence mediation model is

$$M(t) = \int_{\Omega_1^t} Z(s)\alpha(s,t)ds + \epsilon_1(t),$$

$$Y(t) = \int_{\Omega_2^t} Z(s)\gamma(s,t)ds + \int_{\Omega_3^t} M(s)\beta(s,t)ds + \epsilon_2(t),$$

where $\alpha(s,t)$, $\beta(s,t)$, $\gamma(s,t)$ are coefficient curves; $\Omega_t^j = [(t - \delta_j) \vee 0, t]$ for $j = 1, 2, 3$. The model coefficient curves are estimated by minimizing the penalized L_2 -loss. Tuning parameter λ controls the smoothness of the estimated curves, and is chosen by cross-validation.

Value

basis1	the basis functions on the s domain used in the analysis.
basis2	the basis functions on the t domain used in the analysis.
M	a list of output for the mediator model coefficient: the estimated coefficient with respect to the basis function curve: the estimated coefficient curve fitted: the fitted value of M lambda1: the chosen λ value on the s domain lambda2: the chosen λ value on the t domain
Y	a list of output for the outcome model coefficient: the estimated coefficient with respect to the basis function curve: the estimated coefficient curve fitted: the fitted value of Y lambda1: the chosen λ value on the s domain lambda2: the chosen λ value on the t domain
IE	a list of output for the indirect effect comparing $Z_1(t) = 1$ versus $Z_0(t) = 0$ curve: the estimated causal curve
DE	a list of output for the direct effect comparing $Z_1(t) = 1$ versus $Z_0(t) = 0$ curve: the estimated causal curve

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References

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Examples

```
#####  
# Historical influence functional mediation model  
data(env.historical)  
Z<-get("Z",env.historical)  
M<-get("M",env.historical)  
Y<-get("Y",env.historical)  
  
## Not run:  
# consider Fourier basis  
fit<-FMA.historical.CV(Z,M,Y,delta.grid1=3,delta.grid2=3,delta.grid3=3,  
  intercept=FALSE,timeinv=c(0,300))  
  
## End(Not run)  
#####
```

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