Package ‘splmm’

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Title Simultaneous Penalized Linear Mixed Effects Models
Version 1.1.3
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Maintainer Luoying Yang <lyang19@u.rochester.edu>
Description Contains functions that fit linear mixed-effects models
for high-dimensional data (p>>n) with penalty for both the fixed effects and random ef-
fects for variable selection.
The details of the algorithm can be found in Luoying Yang PhD the-
sis (Yang and Wu 2020). The algorithm implementation
is based on the R package 'lmmlasso'.
Reference: Yang L, Wu TT (2020). Model-Based Clustering of Longitudinal Data in High-
License GPL-3
Imports Rcpp (>= 1.0.1), emulator, miscTools, penalized, ggplot2,
gridExtra, plot3D, MASS
LinkingTo Rcpp, RcppArmadillo
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Description

Contains functions that fit linear mixed-effects models for high-dimensional data (p\n n) with penalty for both the fixed effects and random effects for variable selection. The details of the algorithm can be found in Luoying Yang PhD thesis (Yang and Wu 2020). The algorithm implementation is based on the R package 'ltmmlasso'. Reference: Yang L, Wu TT (2020). Model-Based Clustering of Longitudinal Data in High-Dimensionality. Unpublished thesis.

Details

The DESCRIPTION file:

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Author: Luoying Yang [aut, cre], Tong Tong Wu [aut]

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Contains functions that fit linear mixed-effects models for high-dimensional data (p>n) with penalty for both the fixed effects and random effects for variable selection.

Author(s)

NA

Maintainer: Luoying Yang <lyang19@u.rochester.edu>

References

Luoying Yang PhD thesis


Examples

## Use splmm on the Kenya school cognitive data set

data(cognitive)

x <- model.matrix(ravens ~schoolid+treatment+year+sex+age_at_time0
  +height+weight+head_circ+ses+mom_read+mom_write
  +mom_edu, cognitive)

z <- x

fit <- splmm(x=x,y=cognitive$ravens,z=z,grp=cognitive$id, lam1=0.1,
  lam2=0.1,penalty.b="lasso", penalty.L="lasso")

summary(fit)
**Kenya School Lunch Intervention Cognitive Dataset**

**Description**

In the Kenya school lunch intervention, children were given one of four school lunch interventions: meat, milk, calorie, or control. The first three groups were fed a school lunch of a stew called githeri supplemented with either meat, milk, or oil to create a lunch with a given caloric level, while the control group did not receive a lunch. Three schools were randomized to each group and the lunch program is the same for all children within a school. The data is available in *modeling-longitudinal-data-rob-weiss* and is broken up into sub data sets from four domains: Anthropometry, Cognitive, Morbidity, and Nutrition. We will be using the cognitive dataset for analyzing how the cognition level of the school children change over time and how the change is associated with other variables. The main cognitive measures is Raven’s colored progressive matrices (Raven’s), a measure of cognitive ability. There are three additional response variables: arithmetic score (arithmetic), verbal meaning (vmeaning), and total digit span score (dstotal) where digit span is a test of memory while others are considered measures of intelligence or education. The cognitive measurement baseline was taken prior to the lunch program onset and measurements were assessed at up to five times, called rounds, for each subject. More information about this dataset please see the reference: Robert E Weiss. Modeling longitudinal data. Springer Science & Business Media, 2005.

**Usage**

```r
data(cognitive)
```

**Format**

A data frame of 1562 observations and 26 variables.

- Grouping variable. Unique ID for each subject.
- `schoolid` School id 1-12.
- `treatment` Calorie, meat, milk, control
- `rn` round.
- `year` Time in years from baseline.
- `revans` Raven’s colored matrices score.
- `arithmetic` Arithmetic score.
- `vmeaning` Verbal meaning.
- `dstotal` Total digit span score.
- `sex` Girl or Boy.
- `age_at_time0` age at baseline.
- `height` height at baseline.
- `weight` weight at baseline.
- `head_circ` Head circumference at baseline.
ses  Socio-Economic Status score.

mom_read  Mother’s reading test.

mom_write  Mother’s writing test.

mom_edu  Mother’s years of educations.

morbscore  Morbidity score: none/mild/severe.

complete  Logical variable specifying whether the subject has all five rounds. 1-Yes, 0-No.

rnone  Logical variable specifying whether the observation is the baseline. 1-round one (baseline), 0-not round one.

relmonth  Time in months from baseline.

Examples

```r
data(cognitive)
```

---

**Description**

This function inputs an `splmm.tuning` object and plot the model selection criterion values over the tuning parameters grid.

**Usage**

```r
## S3 method for class 'splmm'
plot(x, ...)
```

**Arguments**

- `x` a `splmm.tuning` object
- `...` not used

**Value**

A line plot of BIC, AIC, BICC, EBIC values against lam1 or lam2 depending on the inout.

**See Also**

`plot.splmm`
Examples

```r
data(cognitive)

x <- model.matrix(ravens ~ schoolid+treatment+year+sex+age_at_time0 + height+weight+head_circ+ses+mom_read+mom_write + mom_edu, cognitive)
z <- x

## Tuning over lambda1 grid
lam1 = seq(0.1,0.5,0.1)
lam2 = 0.1
fit1 <- splmmTuning(x=x,y=cognitive$ravens,z=z,grp=cognitive$id, lam1=lam1, lam2=lam2, penalty.b="scad", penalty.L="scad")
plot.splmm(fit1)
```

---

**plot3D.splmm**

3D Plot the tuning results of a 'splmm.tuning' object when tuning over both lambda 1 and lambda 2 grids

---

**Description**

This function inputs an 'splmm.tuning' object and plot the model selection criterion values in a 3D plot over the lambda 1 and lambda 2 tuning parameters grid.

**Usage**

```r
## S3 method for class 'splmm'
plot3D(x, criteria=c("BIC","AIC","BICC","EBIC"),type=c("line","surface"),...)
```

**Arguments**

- `x` a 'splmm.tuning' object with both lam1.tuning=TRUE and lam2.tuning=TRUE
- `criteria` A parameter specifying whether the criteria value the user want to plot is BIC, AIC, BICC or EBIC. The default is BIC
- `type` A parameter specifying which type of 3D plot to use for plotting. Currently the available options include line plot and surface plot. The default is surface plot.
- `...` not used

**Value**

A 3D line/surface plot of BIC/AIC/BICC/EBIC values against lam1 and lam2.
print.splmm

See Also

plot3D

Examples

data(cognitive)
x <- model.matrix(ravens ~ schoolid + treatment + year + sex + age_at_time0 + height + weight + head_circ + ses + mom_read + mom_write + mom_edu, cognitive)

z <- x

## Tuning over lambda1 grid and lambda2 grid
lam1 = seq(0.1, 0.5, 0.1)
lam2 = seq(0.1, 0.5, 0.1)
fit1 <- splmmTuning(x=x, y=cognitive$ravens, z=z, grp=cognitive$id, lam1=lam1, lam2=lam2, penalty.b="scad", penalty.L="scad")
plot3D.splmm(fit1)

print.splmm

Print a short summary of a splmm object.

Description

Prints a short summary of an 'splmm' object comprising information about the nonzero fixed-effects coefficients and the nonzero random effect variance components.

Usage

## S3 method for class 'splmm'
print(x, ...)

Arguments

x a 'splmm' object
...
not used

Value

No return value, a print-out of a 'splmm' object's short summary is produced.

See Also

print.splmm
Examples

```r
set.seed(144)
fit = splmm(x=simulated_data$x, y=simulated_data$y,
z=simulated_data$z, grp=simulated_data$grp,
lam1=0.1, lam2=0.01, penalty.b="scad", penalty.L="scad")
print(fit)
```

```r
data(cognitive)
x <- model.matrix(ravens ~ schoolid + treatment + year + sex + age_at_time0 + height + weight + head_circ + ses + mom_read + mom_write + mom_edu, cognitive)

z <- x

fit <- splmm(x=x, y=cognitive$ravens, z=z, grp=cognitive$id, lam1=0.1, lam2=0.1, penalty.b="scad", penalty.L="scad")
print(fit)
```
Function to fit linear mixed-effects model with double penalty for fixed effects and random effects

Description
All the details of the algorithm can be found in the manuscript.

Usage
```
splmm(x, y, z, grp, lam1, lam2, nonpen.b=1, nonpen.L=1, penalty.b=c("lasso", "scad"),
      penalty.L=c("lasso", "scad"), CovOpt=c("nlminb", "optimize"),
      standardize=TRUE, control=splmmControl())
```

Arguments
- **x**: matrix of dimension N x p including the fixed-effects covariables. An intercept has to be included in the first column as (1,...,1).
- **y**: response variable of length N.
- **z**: random effects matrix of dimension N x q. It has to be a matrix, even if q=1.
- **grp**: grouping variable of length N
- **lam1**: regularization parameter for fixed effects penalization.
- **lam2**: regularization parameter for random effects penalization.
- **nonpen.b**: Index of indices of fixed effects not penalized. The default value is 1, which means the fixed intercept is not penalized
- **nonpen.L**: Index of indices of random effects not penalized. The default value is 1, which means the random intercept is not penalized
- **penalty.b**: The penalty method for fixed effects penalization. Currently available options include LASSO penalty and SCAD penalty.
- **penalty.L**: The penalty method for fixed effects penalization. Currently available options include LASSO penalty and SCAD penalty.
- **CovOpt**: which optimization routine should be used for updating the variance parameter. The available options include optimize and nlminb. nlminb uses the estimate of the last iteration as a starting value. nlminb is faster if there are many Gauss-Seidel iterations.
- **standardize**: A logical parameter specifying whether the fixed effects matrix x and random effects matrix z should be standardized such that each column has mean 0 and standard deviation 1. The default value is TRUE
- **control**: control parameters for the algorithm and the Armijo Rule, see `splmmControl` for the details
Value

A `splmm` object is returned, for which coef, resid, fitted, print, summary methods exist.

data data set used for fitting the model, as a list with four components: x, y, z, grp (see above)
coeffInit list of the starting values for beta, random effects covariance structure, and variance structure
penalty.b The penalty method for fixed effects penalization.
penalty.L The penalty method for random effects penalization.
nonpen.b Index of indices of fixed effects not penalized.
nonpen.L Index of indices of random effects not penalized.
lambda1 regularization parameter for fixed effects penalization scaled by the number of subjects.
lambda2 regularization parameter for random effects penalization scaled by the number of subjects.
sigma standard deviation \( \hat{\sigma} \) of the errors
D The estimates of the random effects covariance matrix \( \hat{D} \).
Lvec Vectorized \( \hat{L} \), the lower triangular matrix of \( \hat{D} \) from Cholesky Decomposition.
coefficients estimated fixed-effects coefficients \( \hat{\beta} \)
random vector with random effects, sorted by groups
ranef vector with random effects, sorted by effect
u vector with the standardized random effects, sorted by effect
fixef estimated fixed-effects coefficients \( \hat{\beta} \)
fitted.values The fitted values \( \hat{y} = \hat{X}\beta + \hat{Z} \hat{b}_i \)
residuals raw residuals \( y - \hat{y} \)
corD Correlation matrix of the random effects
logLik value of the log-likelihood function
deviance deviance=\(-2\text{logLik}\)
npar Number of parameters. Corresponds to the cardinality of the set of nonzero coefficients plus the number of nonzero variance in D
aic AIC
bic BIC
biccc Modified BIC defined by Wang et al (2009)
ebic Extended BIC defined by Chen and Chen (2008)
converged Does the algorithm converge? 0: correct convergence; an odd number means that maxIter was reached; an even number means that the Armijo step was not successful. For each unsuccessful Armijo step, 2 is added to converged. If converged is large compared to the number of iterations counter, you may increase maxArmijo.
counter The number of iterations used.
<table>
<thead>
<tr>
<th>splmmControl Options for the 'splmm' Algorithm</th>
</tr>
</thead>
</table>

**Description**

Definition of various kinds of options in the algorithm.

**Usage**

```r
splmmControl(tol=10^(-4),trace=1,maxIter=1000,maxArmijo=20,number=5,a_init=1,
delta=0.1,rho=0.001,gamma=0,lower=10^(-6),upper=10^8,seed=532,VarInt=c(0,10),
CovInt=c(-5,5),thres=10^(-4))
```
Arguments

tol convergence tolerance
trace integer. 1 prints no output, 2 prints warnings, 3 prints the current function values and warnings (not recommended)
maxIter maximum number of (outer) iterations
maxArmijo maximum number of steps to be chosen in the Armijo Rule. If the maximum is reached, the algorithm continues with optimizing the next coordinate.
number integer. Determines the active set algorithm. The zero fixed-effects coefficients are only updated each number iteration. It may be that a smaller number increases the speed of the algorithm. Use $0 \leq \text{number} \leq 5$.
a_init $\alpha_{\text{init}}$ in the Armijo step. See Schelldorfer et. al. (2010).
delta $\delta$ in the Armijo step. See Schelldorfer et. al. (2010)
rho $\rho$ in the Armijo step. See Schelldorfer et. al. (2010)
gamma $\gamma$ in the Armijo step. See Schelldorfer et. al. (2010)
lower lower bound for the Hessian
upper upper bound for the Hessian
seed set.seed for calculating the starting value, which performs a 10-fold cross-validation.
VarInt Only for opt="optimize". The interval for the variance parameters used in "optimize". See help("optimize")
CovInt Only for opt="optimize". The interval for the covariance parameters used in "optimize". See help("optimize")
thres If a variance or covariance parameter has smaller absolute value than thres, the parameter is set to exactly zero.

Details

For the Armijo step parameters, see Bertsekas (2003)

Value

Exactly the same as arguments.

Description

This function fits ‘splm’ function over grids of lambda1 and/or lambda2 and determine the best fit model based on model selection information criterion. The function takes a scalar or a grid of lambda1 and/or lambda2 and determine the optimal tuning parameter value for the best model fit. If both lambda1 and lambda2 are inputted as scalars, an ‘splm’ object is returned; if either or both lambda1 and lambda2 are inputted as grids, an ‘splm.tuning’ object is returned. Currently the model selection criterion include AIC and BIC, and BIC is used to determine the optimal model.
Usage

splmmTuning(x, y, z, grp, lam1.seq, lam2.seq, nonpen.b=1, nonpen.L=1,
penalty.b=c("lasso","scad"),
penalty.L=c("lasso","scad"),
CovOpt=c("nlminb","optimize"),
standardize=TRUE,control=splmmControl())

Arguments

x matrix of dimension N x p including the fixed-effects covariables. An intercept has to be included in the first column as (1,...,1).
y response variable of length N.
z random effects matrix of dimension N x q. It has to be a matrix, even if q=1.
grp grouping variable of length N
lam1.seq a grid of regularization parameter for fixed effects penalization, could be a scalar if no need to tune.
lam2.seq a grid of regularization parameter for random effects penalization, could be a scalar if no need to tune.
nonpen.b Index of indices of fixed effects not penalized. The default value is 1, which means the fixed intercept is not penalized.
nonpen.L Index of indices of random effects not penalized. The default value is 1, which means the random intercept is not penalized.
penalty.b The penalty method for fixed effects penalization. Currently available options include LASSO penalty and SCAD penalty.
penalty.L The penalty method for fixed effects penalization. Currently available options include LASSO penalty and SCAD penalty.
CovOpt which optimization routine should be used for updating the variance parameter. The available options include optimize and nlminb. nlminb uses the estimate of the last iteration as a starting value. nlminb is faster if there are many Gauss-Seidel iterations.
standardize A logical parameter specifying whether the fixed effects matrix x and random effects matrix z should be standardized such that each column has mean 0 and standard deviation 1. The default value is TRUE.
control control parameters for the algorithm and the Armijo Rule, see ‘splmmControl’ for the details.

Value

A 'splmm.tuning' object is returned, for which plot method exist.

lam1.seq lambda1 grid used for tuning. Only available when lambda1 is inputted as a vector.

lam2.seq lambda2 grid used for tuning. Only available when lambda2 is inputted as a vector.
BIC.lam1  A vector of BIC values of splmm models fitting over a lambda1 grid.
BIC.lam2  A vector of BIC values of splmm models fitting over a lambda2 grid.
fit.BIC   An array of BIC values of splmm models fitting over lambda 1 grid x lambda2 grid.
AIC.lam1  A vector of AIC values of splmm models fitting over a lambda1 grid.
AIC.lam2  A vector of AIC values of splmm models fitting over a lambda2 grid.
fit.AIC   An array of AIC values of splmm models fitting over lambda 1 grid x lambda2 grid.
BICC.lam1 A vector of BICC values of splmm models fitting over a lambda1 grid.
BICC.lam2 A vector of BICC values of splmm models fitting over a lambda2 grid.
fit.BICC An array of BICC values of splmm models fitting over lambda 1 grid x lambda2 grid.
EBIC.lam1 A vector of EBIC values of splmm models fitting over a lambda1 grid.
EBIC.lam2 A vector of EBIC values of splmm models fitting over a lambda2 grid.
fit.EBIC  An array of EBIC values of splmm models fitting over lambda 1 grid x lambda2 grid.
min.BIC   The minimum BIC value from tuning over a grid. This is only available when either lambda1 or lambda2 is a scalar.
min.AIC   The minimum AIC value from tuning over a grid. This is only available when either lambda1 or lambda2 is a scalar.
min.BICC  The minimum BICC value from tuning over a grid. This is only available when either lambda1 or lambda2 is a scalar.
min.EBIC  The minimum EBIC value from tuning over a grid. This is only available when either lambda1 or lambda2 is a scalar.
best.model The index of the optimal model. This is only available when either lambda1 or lambda2 is a scalar.
best.fit  The optimal model chosen by the minimum BIC as an splmm object.
min.lam1  lambda1 value that results in the optimal model. This is only available when input lambda1 is a vector.
min.lam2  lambda2 value that results in the optimal model. This is only available when input lambda2 is a vector.
lam1.tuning A logical parameter specifying if tuning is performed over lambda1 grid. lam1.tuning=TRUE if input lambda1 is a vector.
lam2.tuning A logical parameter specifying if tuning is performed over lambda2 grid. lam1.tuning=TRUE if input lambda2 is a vector.

Examples

data(cognitive)
x <- model.matrix(ravens ~schoolid+treatment+year+sex+age_at_time0
z <- x

## Tuning over lambda1 grid
lam1 = seq(0.1,0.5,0.1)
lam2 = 0.1
fit1 <- splmmTuning(x=x, y=cognitive$ravens, z=z, grp=cognitive$id, lam1.seq=lam1, lam2.seq=lam2, penalty.b="scad", penalty.L="scad")
plot.splmm(fit1)

## Tuning over lambda2 grid
lam1 = 0.1
lam2 = seq(0.1,0.5,0.1)
fit2 <- splmmTuning(x=x, y=cognitive$ravens, z=z, grp=cognitive$id, lam1.seq=lam1, lam2.seq=lam2, penalty.b="scad", penalty.L="scad")
plot.splmm(fit2)

## Tuning over both lambda1 and lambda2 grid
lam1 = seq(0.1,0.5,0.2)
lam2 = seq(0.1,0.5,0.2)
fit3 <- splmmTuning(x=x, y=cognitive$ravens, z=z, grp=cognitive$id, lam1.seq=lam1, lam2.seq=lam2, penalty.b="scad", penalty.L="scad")
plot.splmm(fit3)

---

### summary.splmm

**Summarize an ‘splmm’ object**

**Description**

Providing an elaborate summary of a ‘splmm’ object.

**Usage**

```r
## S3 method for class ‘splmm’
summary(object, ...)
```

**Arguments**

- `object` a ‘splmm’ object
- `...` not used.

**Details**

This functions shows a detailed summary of a ‘splmm’ object.
Value

No return value, a print-out of a 'splmm' object's detailed summary is produced.

Examples

data(simulated_data)

set.seed(144)
fit = splmm(x=simulated_data$x, y=simulated_data$y, 
z=simulated_data$z, grp=simulated_data$grp, 
lam1=0.1, lam2=0.01, penalty.b="scad", penalty.L="scad")
summary(fit)

data(cognitive)

x <- model.matrix(ravens ~ schoolid+treatment+year+sex+age_at_time0 
                  +height+weight+head_circ+ses+mom_read+mom_write 
                  +mom_edu, cognitive)
z <- x

fit <- splmm(x=x, y=cognitive$ravens, z=z, grp=cognitive$id, lam1=0.1, lam2=0.1, 
              penalty.b="scad", penalty.L="scad")
summary(fit)
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