Package ‘LMest’

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Description Fit certain versions of the Latent Markov model for longitudinal categorical data.
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LMest-package

Description

Set of functions to fit latent Markov models in the basic version and in the extended version with individual covariates.
The most important functions are `est_lm_basic`, `est_lm_cov_manifest`, and `est_lm_cov_latent` which estimate the basic LM model and its extensions including covariates.

**Author(s)**

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**References**


**Examples**

```r
# Example of drug consumption data
# load data
data(data_drug)
data_drug = as.matrix(data_drug)
S = data_drug[,1:5]-1
yv = data_drug[,6]
n = sum(yv)
# fit of the Basic LC model
k = 3
out1 = est_lm_basic(S,yv,k,mod=1,out_se=TRUE)
## Not run:
out2 = bootstrap_lm_basic(out1$piv,out1$P1,out1$Psi,n,mod=1,B=1000)
## End(Not run)
```

---

**blkdiag**

**Build a block diagonal matrix.**

**Description**

Function to build a block diagonal matrix (internal function).

**Usage**

```r
blkdiag(A,B)
```
Arguments

A The first non-empty, numeric matrix
B The second non-empty, numeric matrix

Value

C A numeric block diagonal matrix

Author(s)

Francesco Bartolucci, Silvia Pandolfi - University of Perugia (IT)

bootstrap_lm_basic

Parametric bootstrap for the basic LM model

Description

Function that performs bootstrap parametric resampling to compute standard errors for the parameter estimates.

Usage

bootstrap_lm_basic(piv, Pi, Psi, n, B = 100, start = 0, mod = 0, tol = 10^-6)

Arguments

piv initial probability vector
Pi probability transition matrices
Psi matrix of conditional response probabilities
n sample size
B number of bootstrap samples
start type of starting values (0 = deterministic, 1 = random)
mod model on the transition probabilities (0 for time-heter., 1 for time-homog., 2-(TT-1) partial homog. of that order)
tol tolerance level for convergence

Value

mPsi average of bootstrap estimates of the conditional response matrix
mpiv average of bootstrap estimates of the initial probability vector
mPi average of bootstrap estimates of the transition probability matrices
sePsi standard errors for the conditional response matrix
sepi standard errors for the initial probability vector
sepi standard errors for the transition probability matrices
### Examples

```r
## Not run:
# Example of drug consumption data
# load data
data(data_drug)
data_drug = as.matrix(data_drug)
S = data_drug[,1:5]-1
yv = data_drug[,6]
n = sum(yv)

# fit of the Basic LC model
k = 3
out1 = est_lm_basic(S,yv,k,mod=1,out_se=T)
out2 = bootstrap_lm_basic(out1$pi1,out1$pi2,out1$psi,n,mod=1,B=1000)

## End(Not run)
```

### Description

Function that performs bootstrap parametric resampling to compute standard errors for the parameter estimates.

### Usage

```r
bootstrap_lm_cov_latent(X1,X2,param=*multilogit*,Psi,Be,Ga,B=1000,fort=TRUE)
```

### Arguments

- **X1**: matrix of the initial probabilities (n x nc1)
- **X2**: array of the transition probabilities (n x TT-1 x nc2)
- **param**: type of parametrization for the transition probabilities ("multilogit" = standard multinomial logit for every row of the transition matrix, "difflogit" = multinomial logit based on the difference between two sets of parameters)
- **Psi**: matrix of conditional response probabilities
- **Be**: parameters affecting the logit for the initial probabilities
- **Ga**: parameters affecting the logit for the transition probabilities
- **B**: number of bootstrap samples
- **fort**: to use fortran routine when possible (FALSE for not use fortran)
Value

- **mPsi**: average of bootstrap estimates of the conditional response matrix
- **mBe**: average of bootstrap estimates of the parameters affecting the logit for the initial probabilities
- **mGa**: average of bootstrap estimates of the parameters affecting the logit for the transition probabilities
- **sePsi**: standard errors for the conditional response matrix
- **seBe**: standard errors for the parameters in Be
- **seGa**: standard errors for the parameters in Ga

Author(s)

Francesco Bartolucci, Silvia Pandolfi - University of Perugia (IT)

Examples

```r
## Not run:
## Example based on self-rated health status (SRHS) data
## load SRHS data
data(data_SRHS_long)
data = data_SRHS_long

TT = 8
head(data)
res = long2matrices(data$id,cbind(data$gender-1,data$race==2|data$race==3,
data$education==4,data$education==5,data$age-50,(data$age-50)^2/100),data$srh)

# matrix of responses (with ordered categories from 0 to 4)
S = 5-res$yy

# matrix of covariates (for the first and the following occasions)
# columns are: gender, race, educational level (2 columns), age, age^2
X1 =res$XX[,1,]
X2 =res$XX[,2:TT,]

# estimate the model
out1 = est_lm_cov_latent(S,X1,X2,k=2,output=TRUE,out_se=TRUE)
out2 = bootstrap_lm_cov_latent(X1,X2,Psi=out1$Psi,Be=out1$Be,Ga=out1$Ga,B=1000)
## End(Not run)
```

complk

**Complete log-likelihood of the basic latent Markov model**

Description

Function that computes complete log-likelihood of the latent Markov model (internal use).
**data_criminal_sim**

**Usage**

```r
complk(S, yv, piv, Pi, Psi, k)
```

**Arguments**

- `S`: matrix of distinct response configurations ($n \times TT \times r$)
- `yv`: corresponding vector of frequencies
- `piv`: vector of initial probabilities
- `Pi`: transition probability matrix
- `Psi`: conditional response probabilities
- `k`: number of latent classes

**Value**

- `lk`: log-likelihood
- `Phi`: matrix of the conditional probabilities of the observed response configurations
- `L`: matrix of the forward probabilities
- `pv`: vector of marginal probabilities

**Author(s)**

Francesco Bartolucci, Silvia Pandolfi, University of Perugia (IT), http://www.stat.unipg.it/bartolucci

**References**


---

**data_criminal_sim**  *Criminal dataset*

**Description**

Simulated dataset about crimes committed by a cohort of subjects.

**Usage**

```r
data(data_criminal_sim)
```
Format

A data frame with 10000 observations on the following 13 variables.

id  subject id
sex  gender of the subject
time occasion of observation
y1  crime of type 1
y2  crime of type 2
y3  crime of type 3
y4  crime of type 4
y5  crime of type 5
y6  crime of type 6
y7  crime of type 7
y8  crime of type 8
y9  crime of type 9
y10 crime of type 10

References


Examples

data(data_criminal_sim)

---

Data_drug  Dataset about marijuana consumption

Description

Longitudinal dataset about marijuana consumption measured by ordinal variables with 3 categories.

Usage

data(data_drug)

Format

A data frame with 51 observations on the following 6 variables.

v1  reported drug use at the 1st occasion
v2  reported drug use at the 2nd occasion
v3  reported drug use at the 3rd occasion
v4  reported drug use at the 4th occasion
v5  reported drug use at the 5th occasion
v6  frequency of the response configuration
Source

References

Examples
data(data_drug)

data_SRHS_long

*Self-reported health status dataset*

Description
Dataset about self-reported health status derived from the Health and Retirement Study conducted by the University of Michigan.

Usage
data(data_SRHS_long)

Format
A data frame with 56592 observations on the following 6 variables.

id subject id
gender gender of the subject
race race
education educational level
age age at the different time occasions
srhs self-reported health status at the different time occasions

References

Examples
data(data_SRHS_long)
decoding

Perform local and global decoding

Description

Function that performs local decoding and global decoding (Viterbi) from the output of est_lm_basic, est_lm_cov_latent, est_lm_cov_manifest, and est_lm_mixed.

Usage

decoding(est,Y,X1=NULL,X2=NULL,fort=TRUE)

Arguments

- **est**: output from est_lm_basic, est_lm_cov_latent, est_lm_cov_manifest, or est_lm_mixed
- **Y**: single vector or matrix of responses
- **X1**: matrix of covariates on the initial probabilities (est_lm_cov_latent) or on the responses (est_lm_cov_manifest)
- **X2**: array of covariates on the transition probabilities
- **fort**: to use Fortran routines

Value

- **Ul**: matrix of local decoded states corresponding to each row of Y
- **Ug**: matrix of global decoded states corresponding to each row of Y

Author(s)

Francesco Bartolucci, Silvia Pandolfi, University of Perugia (IT), http://www.stat.unipg.it/bartolucci

Examples

# example for the output from est_lm_basic
data(data_drug)
data_drug = as.matrix(data_drug)
S = data_drug[,1:5]
yv = data_drug[,6]
n = sum(yv)
# fit of the Basic LC model
k = 3
est = est_lm_basic(S,yv,k,mod=1)
# decoding for a single sequence
out1 = decoding(est,S[1,])
# decoding for all sequences
out2 = decoding(est,S)
# example for the output from est_lm_cov_latent with difflogit parametrization

data(data_SRHS_long)
data = data_SRHS_long[1:1600,]

TT = 8
head(data)
res = long2matrices(data$id,cbind(data$gender==1,data$race==2,data$race==3,
data$education==4,data$education==5,data$age==50,(data$age==50)*2/100),data$srhs)

# matrix of responses (with ordered categories from 0 to 4)
S = 5-res$YY

# matrix of covariates (for the first and the following occasions)
# columns are: gender, race, educational level (2 columns), age, age^2
X1 =res$XX[,1,]
X2 =res$XX[,2:TT,]

# estimate the model
est = est_lm_cov_latent(S,X1,X2,k=2,output=TRUE,param="difflogit")
# decoding for a single sequence
out1 = decoding(est,S[,],X1[,],X2[1,])
# decoding for all sequences
out2 = decoding(est,S,X1,X2)

---

draw_lm_basic  

**Draw samples from the basic LM model**

**Description**

Function that draws samples from the basic LM model with specific parameters.

**Usage**

draw_lm_basic(piv, Pi, Psi, n)

**Arguments**

- **piv**: vector of initial probabilities of the latent Markov chain
- **Pi**: set of transition matrices
- **Psi**: matrix of conditional response probabilities
- **n**: sample size

**Value**

- **Y**: matrix of response configurations unit by unit
- **S**: matrix of distinct response configurations
- **yv**: corresponding vector of frequencies
draw_lm_cov_latent

Draw samples from LM model with covariates in the latent model

Description

Function that draws samples from the LM model with individual covariates with specific parameters.

Usage

draw_lm_cov_latent(X1, X2, param="multilogit", Psi, Be, Ga, fort=TRUE)

Arguments

X1 desing matrix for the initial probabilities (n x nc1)
X2 desing matrix for the transition probabilities (n x T-1 x nc2)
param type of parametrization for the transition probabilities ("multilogit" = standard multinomial logit for every row of the transition matrix, "difflogit" = multinomial logit based on the difference between two sets of parameters)
Psi matrix of conditional response probabilities
Be parameters affecting the logit for the initial probabilities
Ga parameters affecting the logit for the transition probabilities
fort to use fortran routine when possible (FALSE for not use fortran)

Value

Y matrix of response configurations unit by unit
U matrix containing the sequence of latent states

Author(s)

Francesco Bartolucci, Silvia Pandolfi, University of Perugia (IT), http://www.stat.unipg.it/bartolucci
**Examples**

```r
# draw a sample for 1000 units, 10 response variable and 2 covariates
n=1000
TT = 5
k=2
nc = 2
r = 10
fort=TRUE

Psi = matrix(c(0.9,0.1,0.1,0.9),2,k)
Psi = array(Psi,c(2,k,r))
Ga = matrix(c(-log(0.9/0.1),0.5,1),((nc+1)*(k-1),k)
Be = array(c(0,0.5,1),((nc+1)*(k-1)))

#Simulate covariates
X1 = matrix(0,n,nc)
for(j in 1:nc) X1[,j]=rnorm(n)
X2 = array(0,c(n,TT-1,nc))
for (t in 1:(TT-1)) for(j in 1:nc){
  if(t==1){
    X2[t,j] = 0.5*X1[,j]+rnorm(n)
  } else{
    X2[t,j] = 0.5*X2[,t-1,j]+rnorm(n)
  }
}

out = draw_lm_cov_latent(X1,X2,Psi=Psi,Be=Be,Ga=Ga,fort=fort)
```

---

**draw_lm_mixed**

*Draws samples from the mixed LM model*

**Description**

Function that draws samples from the mixed LM model with specific parameters.

**Usage**

```
draw_lm_mixed(la, Piv, Pi, Psi, n, TT)
```

**Arguments**

- `la` vector of mass probabilities for the first latent variable
- `Piv` matrix of initial probabilities of the latent Markov chain (k2 x k1)
- `Pi` set of transition matrices (k2 x k2 x k1)
- `Psi` array of conditional response probabilites (l x k2 x r)
- `n` sample size
- `TT` number of time occasions
Value

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>matrix of response configurations unit by unit</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>matrix of distinct response configurations</td>
<td></td>
</tr>
<tr>
<td>yv</td>
<td>corresponding vector of frequencies</td>
<td></td>
</tr>
</tbody>
</table>

Author(s)

Francesco Bartolucci, Silvia Pandolfi, University of Perugia (IT), http://www.stat.unipg.it/bartolucci

Examples

```r
# draw a sample for 1000 units and only one response variable and 5 time occasions
k1 = 2; k2 = 3
la = rep(1/k1,k1)
Piv = matrix(1/k2,k2,k1)
Pi = array(0,c(k2,k2,k1))
Pi[,1] = diag(k2)
Pi[,2] = 1/k2
Psi = cbind(c(0.6,0.3,0.1),c(0.1,0.3,0.6))
out = draw_lm_mixed(la,Piv,Pi,Psi,n=1000,TT=5)
```

---

est_lm_basic

Estimate basic LM model

Description

Main function for estimating the basic LM model.

Usage

```r
est_lm_basic(S, yv, k, start = 0, mod = 0, tol = 10^-8, maxit = 1000, out_se=FALSE)
```

Arguments

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>array of available configurations (n x TT x r)</td>
<td></td>
</tr>
<tr>
<td>yv</td>
<td>vector of frequencies of the available configurations</td>
<td></td>
</tr>
<tr>
<td>k</td>
<td>number of latent states</td>
<td></td>
</tr>
<tr>
<td>start</td>
<td>type of starting values (0 = deterministic, 1 = random)</td>
<td></td>
</tr>
<tr>
<td>mod</td>
<td>model on the transition probabilities (0 for time-heter., 1 for time-homog., from 2 to (TT-1) partial homog. of that order)</td>
<td></td>
</tr>
<tr>
<td>tol</td>
<td>tolerance level for convergence</td>
<td></td>
</tr>
<tr>
<td>maxit</td>
<td>maximum number of iterations for convergence</td>
<td></td>
</tr>
<tr>
<td>out_se</td>
<td>to compute the information matrix and standard errors</td>
<td></td>
</tr>
</tbody>
</table>
Value

1k maximum log-likelihood
piv estimate of initial probability vector
Pi estimate of transition probability matrices
Psi estimate of conditional response probabilities
np number of free parameters
aic value of AIC for model selection
bic value of BIC for model selection
lkv log-likelihood trace at every step
V array containing the posterior distribution of the latent states for each response configuration and time occasion
sepiv standard errors for the initial probabilities
sePi standard errors for the transition probabilities
sePsi standard errors for the conditional response probabilities
call command used to call the function

Author(s)

Francesco Bartolucci, Silvia Pandolfi, University of Perugia (IT), http://www.stat.unipg.it/bartolucci

References


Examples

# Example of drug consumption data
# load data
data(data_drug)
data_drug = as.matrix(data_drug)
S = data_drug[,1:5]
yv = data_drug[,6]
n = sum(yv)
# fit of the Basic LC model
k = 3
out = est_lm_basic(S,yv,k,mod=1)

## Not run:
# Example based on criminal data
# load criminal data
data(data_criminal_sim)
data = as.matrix(data_criminal_sim)
out = long2wide(data_criminal_sim,"id","time","sex",
c("y1","y2","y3","y4","y5","y6","y7","y8","y9","y10"),aggr=T,full=0)
XX = out$XX
est_lm_cov_latent

Estimate LM model with covariates in the latent model

Description
Main function for estimating LM model with covariates in the latent model.

Usage
est_lm_cov_latent(S,X1,X2,yv=rep(1,ns),k,start=0,tol=10^-8,maxit=1000,param="multilogit", Psi,Be,Ge,fort=TRUE,output=FALSE,out_se=FALSE,fixPsi=FALSE)

Arguments

S array of available configurations (n x TT x r)
X1 matrix of covariates affecting the initial probabilities (n x nc1)
X2 array of covariates affecting the transition probabilities (n x TT-1 x nc2)
yv vector of frequencies of the available configurations
k number of latent states
start type of starting values (0 = deterministic, 1 = random, 2 = initial values in input)
tol tolerance level for checking convergence of the algorithm
maxit maximum number of iterations for convergence of the algorithm
param type of parametrization for the transition probabilities ("multilogit" = standard multinomial logit for every row of the transition matrix, "dofilogit" = multinomial logit based on the difference between two sets of parameters)
Psi initial value of the matrix of the conditional response probabilities
Be initial value of the parameters affecting the logit for the initial probabilities (if start=2)
Ga initial value of the parameters affecting the logit for the transition probabilities (if start=2)
fort to use fortran routine when possible (FALSE for not use fortran)
output to return additional output (V,PI,Piv,UI)
out_se to compute the information matrix and standard errors
fixPsi TRUE if Psi is given in input and is not updated anymore

Value

lk maximum log-likelihood
Be estimated array of the parameters affecting the logit for the initial probabilities
Ga estimated array of the parameters affecting the logit for the transition probabilities
Piv estimate of initial probability matrix
PI estimate of transition probability matrices
Psi estimate of conditional response probabilities
np number of free parameters
aic value of AIC for model selection
bic value of BIC for model selection
lkv log-likelihood trace at every step
V array containing the posterior distribution of the latent states for each response configuration and time occasion
Ul matrix containing the predicted sequence of latent states by the local decoding method
sePsi standard errors for the conditional response matrix
seBe standard errors for Be
seGa standard errors for Ga
call command used to call the function

Author(s)
Francesco Bartolucci, Silvia Pandolfi, University of Perugia, http://www.stat.unipg.it/bartolucci

References

Examples

## Not run:
# Example based on self-rated health status (SRHS) data
# load SRHS data
data(data_SRHS_long)
data = data_SRHS_long
TT = 8
head(data)
res = long2matrices(data$id,cbind(data$gender-1,data$race==2|data$race==3,
data$education==4,data$education==5,data$age-50,(data$age-50)^2/100),data$srhs)

# matrix of responses (with ordered categories from 0 to 4)
S = res$YY

# matrix of covariates (for the first and the following occasions)
# columns are: gender, race, educational level (2 columns), age, age^2
X1 = res$XX[,1,]
X2 = res$XX[,2:TT,]

# estimate the model
est2f = est_lm_cov_latent(S,X1,X2,k=2,output=TRUE,out_se=TRUE)

# average transition probability matrix
PI = round(apply(est2f$PI[,2:TT],c(1,2),mean),4)

# Transition probability matrix for white females with high educational level
ind1 = (X1[,1]==1 & X1[,2]==0 & X1[,4]==1)
PI1 = round(apply(est2f$PI[,ind1,2:TT],c(1,2),mean),4)

# Transition probability matrix for non-white males, low educational level
ind2 = (X1[,1]==0 & X1[,2]==1 & X1[,3]==0 & X1[,4]==0)
PI2 = round(apply(est2f$PI[,ind2,2:TT],c(1,2),mean),4)

# End(Not run)

---

est_lm_cov_manifest  
Estimate LM model with covariates in the measurement model

Description

Main function for estimating LM model with covariates in the measurement model based on a cumulative logit parameterization.

Usage

est_lm_cov_manifest(S,X,lev,k,q,mod,tol=10^-8,maxit=1000,start=0,mu=NULL,al=NULL,
be=NULL,si=NULL,rho=NULL,la=NULL,PI=NULL,output=FALSE,out_se=FALSE)

Arguments

S  array of available configurations (n x TT)
X  array (n x TT x nc) of covariates with eventually includes lagged response (nc = number of covariates)
lev  number of levels of the variable
k number of latent states
q number of support points for AR
mod model (0 = LM with stationary transition, 1 = finite mixture)
tol tolerance for the convergence (optional) and tolerance of conditional probability
if tol>1 then return
maxit maximum number of iterations for convergence of the algorithm
start equal to 1 for random starting values (optional)
mu starting value for mu (optional)
al starting value for al (optional)
be starting value for be (optional)
si starting value for si (optional)
rho starting value for rho (optional)
la starting value for la (optional)
PI starting value for PI (optional)
output to return additional output (PRED0, PRED1)
out_se TRUE for computing information matrix and standard errors

Value

mu vector of cutpoints
al support points for the latent states
be estimate of the vector of regression parameters
si sigma of the AR process
rho parameter vector for AR
la vector of initial probabilities
PI transition matrix
lk maximum log-likelihood
np number of parameters
aic value of AIC index
bic value of BIC index
PRED0 prediction of latent state
PRED1 prediction of the overall latent effect
sebe standard errors for the regression parameters be
selrho standard errors for logit type transformation of rho
J1 information matrix
call command used to call the function

Author(s)

Francesco Bartolucci, Silvia Pandolfi - University of Perugia (IT)
References


Examples

```r
## Not run:
# Example based on self-rated health status (SRHS) data

# load SRHS data
data(data_SRHS_long)
data = data_SRHS_long
head(data)
lev = 5  # number of response categories for the response variable

res = long2matrices(data$id,cbind(data$gender-1,data$race==2|data$race==3,
data$education==4,data$education==5,data$age<50,(data$age<50)*2/100),data$srhs)

X =res$XX
S = 5-res$YY

# *** fit stationary LM model
res0 = vector("list",10); tol = 10^-6;
for(k in 1:10){
  res0[[k]] = est_lm_cov_manifest(S,X,lev,k,1,mod=0,tol)
  save.image("example_SRHS.RData")
}

# *** fit the mixture latent auto-regressive model
tol = 0.005
res = vector("list",4)
k=1
q = 51
res[[k]] = est_lm_cov_manifest(S,X,lev,k,q,mod=1,tol,output=T)
for(k in 2:4) res[[k]] = est_lm_cov_manifest(S,X,lev,k,q,61,mod=1,tol,output=T)

## End(Not run)
```

---

**est_lm_mixed**

*Estimate mixed LM model*

**Description**

Main function for estimating the mixed LM model with discrete random effect in the latent model.
usage

Usage

est_lm_mixed(S, yv = rep(1, nrow(S)), k1, k2, start = 0, tol = 10^-8, maxit = 1000, out_se = FALSE)

Arguments

S array of available response configurations (n x TT x r)
yv vector of frequencies of the available configurations
k1 number of latent classes
k2 number of latent states
start type of starting values (0 = deterministic, 1 = random)
tol tolerance level for convergence
maxit maximum number of iterations for convergence of the algorithm
out_se to compute standard errors

Value

la estimate of the mass probability vector (distribution of the random effects)
Piv estimate of initial probabilities
Pi estimate of transition probability matrices
Psi estimate of conditional response probabilities
lk maximum log-likelihood
w posterior probabilities of the random effect
np number of free parameters
bic value of BIC for model selection
call command used to call the function

Author(s)

Francesco Bartolucci, Silvia Pandolfi - University of Perugia (IT)

References


Examples

## Not run:
# Example based of criminal data
# load data
data(data_criminal_sim)
data = as.matrix(data_criminal_sim)
out = long2wide(data,"id","time","sex",
c("y1","y2","y3","y4","y5","y6","y7","y8","y9","y10"),aggr=T,full=0)
XX = out$XX

est_multilogit

Description
The function performs maximum likelihood estimation of the multilogit model (internal function).

Usage
```r
est_multilogit(Y, Xdis, label = 1:n, be = NULL, Pdis = NULL,
               dis = FALSE, fort = TRUE, ex = FALSE)
```

Arguments
- `Y`: matrix of all responses
- `Xdis`: array of all covariates (two- or three-dimensional)
- `label`: label associated to every covariate configuration
- `be`: initial value of the parameter vector
- `Pdis`: probability configurations as initial values
- `dis`: to display partial results
- `fort`: to use fortran routines when possible
- `ex`: TRUE if the function exits without running the estimation algorithm providing the score vector and the information matrix

Value
- `be`: estimated vector regression coefficients
- `P`: estimated matrix of probabilities
- `Pdis`: estimated matrix of distinct probabilities
- `sc`: score vector
- `Fi`: information matrix

Author(s)
Francesco Bartolucci, Silvia Pandolfi - University of Perugia (IT)
expit

Compute the expit function.

Description
Function to compute the inverse of the logit function.

Usage
expit(x)

Arguments
x a vector of matrix which contains the values to be transformed

Value
y The transformed sample

Author(s)
Francesco Bartolucci, Silvia Pandolfi - University of Perugia (IT)

expit1

Compute the expit function with respect to a reference category.

Description
Function to compute the inverse of the logit function with respect to a reference category.

Usage
expit1(lp, ref=1)

Arguments
lp a vector which contains the values to be transformed
ref the reference category

Value
p The transformed vector
Der The matrix of derivatives

Author(s)
Francesco Bartolucci, Silvia Pandolfi - University of Perugia (IT)
invglob

Invert vector of global logits.

Description
Function to invert the marginal parametrization based on global logits (internal function).

Usage
invglob(eta)

Arguments
eta vector of global logits

Value
p vector of joint probabilities

Author(s)
Francesco Bartolucci, Silvia Pandolfi, University of Perugia (IT), http://www.stat.unipg.it/bartolucci

lk_ar_rho

Compute complete log-likelihood for AR(1) latent process

Description
Compute the complete log-likelihood for the transition and initial probabilities under the constraint of AR(1) latent process (internal use).

Usage
lk_ar_rho(lrho, SUP, V, outp=FALSE)

Arguments
lrho Fisher transformation of the autocorrelation coefficient
SUP matrix of the support points
V array containing the posterior distribution of the latent states for each response configuration and time occasion
outp to return additional output (Wei, rho)

Value
fFlk Minus the complete log-likelihood
**Author(s)**

Francesco Bartolucci, Silvia Pandolfi - University of Perugia (IT)

---

**Description**

Function that computes complete log-likelihood of the latent Markov model with covariates in the distribution of the latent process (internal use).

**Usage**

```
lk_comp_latent(S,yv,Piv,PI,Psi,k,fort=TRUE,der=FALSE, 
               d1Psi=NULL,d1Piv=NULL,d1PI=NULL)
```

**Arguments**

- `S` matrix of distinct response configurations
- `yv` corresponding vector of frequencies
- `Piv` initial probability matrix
- `PI` transition probability matrices
- `Psi` conditional response probability matrix
- `k` number of latent classes
- `fort` to use fortran routine when possible
- `der` to compute derivatives
- `d1Psi` matrix of derivatives of the logarithm of the conditional response probabilities
- `d1Piv` matrix of derivatives of the logarithm of the initial probabilities
- `d1PI` matrix of derivatives of the logarithm of the transition probabilities

**Value**

- `lk` log-likelihood
- `Phi` matrix of the conditional probabilities of the observed response configurations
- `L` matrix of the forward probabilities
- `pv` vector of marginal probabilities
- `dlk` derivatives of the log-likelihood
- `d1Phi` matrix of derivatives of the log-conditional probabilities of the observed response configurations
- `d1L` matrix of derivatives of the log-forward probabilities
- `d1L2` matrix of second derivatives of the log-forward probabilities
- `dlpv` matrix of derivatives of the log-marginal probabilities
Author(s)
Francesco Bartolucci, Silvia Pandolfi, University of Perugia (IT), http://www.stat.unipg.it/bartolucci

References

Description
Function that computes the observable log-likelihood of the basic LM model.

Usage
```
1k_obs(th, Am, Bm, Cm, b, k, S, yv, TT, r, mod)
```

Arguments
- `th` vector of parameters
- `Am` design matrix for the logits
- `Bm` design matrix for the logits
- `Cm` design matrix for the logits
- `b` number of response categories
- `k` number of states
- `S` matrix of distinct response configurations
- `yv` corresponding vector of frequencies
- `TT` number of times occasions
- `r` number of response variables
- `mod` type of model

Value
- `lk` log-likelihood
- `sc` score vector

Author(s)
Francesco Bartolucci, Silvia Pandolfi, University of Perugia (IT), http://www.stat.unipg.it/bartolucci
lk_obs_latent

**Compute the observable log-likelihood of the LM model with covariates in the latent model**

**Description**

Function that computes the observable log-likelihood of the LM model with covariates in the latent model.

**Usage**

```r
lk_obs_latent(th, S, b, yv, Am, XXdis, Xlab, ZZdis, Zlab, param, fort=TRUE)
```

**Arguments**

- `th`: vector of parameters
- `S`: matrix of distinct response configurations
- `b`: number of response categories
- `yv`: corresponding vector of frequencies
- `Am`: design matrix for the logits
- `XXdis`: design matrix used for estimation of the initial probabilities
- `Xlab`: list of labels used for estimation of the initial probabilities
- `ZZdis`: design matrix used for estimation of the transition probabilities
- `Zlab`: list of labels used for estimation of the transition probabilities
- `param`: type of parametrization for the transition probabilities ("multilogit" = standard multinomial logit for every row of the transition matrix, "difflogit" = multinomial logit based on the difference between two sets of parameters)
- `fort`: to use fortran routine when possible

**Value**

- `lk`: log-likelihood
- `sc`: score vector
- `Psi`: conditional response probabilities
- `be`: parameters on initial probabilities
- `Ga`: parameters on transition probabilities
- `Piv`: initial probabilities
- `PI`: transition probabilities
- `dlPsi`: matrix of derivatives of the logarithm of the conditional response probabilities
- `dlPiv`: matrix of derivatives of the logarithm of the initial probabilities
- `dlPI`: matrix of derivatives of the logarithm of the transition probabilities

**Author(s)**

Francesco Bartolucci, Silvia Pandolfi - University of Perugia (IT)
### lk_obs_manifest

*Compute the observable log-likelihood of the LM model with covariates in the measurement model*

#### Description

Function that computes the observable log-likelihood of the LM model with covariates in the measurement model.

#### Usage

```r
lk_obs_manifest(par, Y, Xd, indn, lev, k, sup, G2, IPI, mod, outp=FALSE)
```

#### Arguments

- `par`: vector of regression parameters
- `Y`: matrix of response variables
- `Xd`: matrix of covariates
- `indn`: index of the design matrix for each unit
- `lev`: vector containing the number of levels of each variable
- `k`: number of latent states
- `sup`: support points
- `G2`: design matrix
- `IPI`: index of the transition matrix elements
- `mod`: model (0 = LM with stationary transition, 1 = finite mixture)
- `outp`: to compute the score of the observable log-likelihood

#### Value

- `lk`: log-likelihood
- `U`: array containing the posterior distribution of the latent states for each response configuration and each pair of consecutive time occasions
- `s`: score of the observable log-likelihood

#### Author(s)

Francesco Bartolucci, Silvia Pandolfi, University of Perugia (IT), http://www.stat.unipg.it/bartolucci
Compute the observable log-likelihood of the mixed LM model

Description

Function that computes the observable log-likelihood of the mixed LM model with discrete random effect in the latent model.

Usage

`lk_obs_mixed(th, nla, nPi, nPs, S, yv, r, k1, k2)`

Arguments

- `th`: vector of parameters
- `nla`: number of logits for the mass probability vector
- `nPiv`: number of logits for the intial probabilities
- `nPi`: number of logits for the transition probabilities
- `nPs`: number of logits for the conditional response probabilities
- `S`: matrix of distinct response configurations
- `yv`: corresponding vector of frequencies
- `r`: number of response variables
- `k1`: number of latent classes
- `k2`: number of latent states

Value

- `lk`: log-likelihood
- `sc`: score vector

Author(s)

Francesco Bartolucci, Silvia Pandolfi - University of Perugia (IT)
**Description**

Function that computes the stationary log-likelihood (internal use).

**Usage**

`lk_sta(tau, u, V, G2, outl=TRUE)`

**Arguments**

- `tau` vector of parameters
- `u` vector of initial posterior probabilities
- `V` sum of the posterior probabilities
- `G2` design matrix
- `outl` to return additional output (la, PI)

**Value**

- `flk` log-likelihood

**Author(s)**

Francesco Bartolucci, Silvia Pandolfi - University of Perugia (IT)

---

**logit1**  
*Compute the logit function with respect to a reference category.*

**Description**

Function to compute the logit function with respect to a reference category.

**Usage**

`logit1(p, ref=1)`

**Arguments**

- `p` a vector which contains the values to be transformed
- `ref` the reference category
**long2matrices**

**Value**

lp  The transformed vector

**Author(s)**

Francesco Bartolucci, Silvia Pandolfi - University of Perugia (IT)

**Description**

Function that transforms data in the long format to data in array format.

**Usage**

long2matrices(id,X,Y)

**Arguments**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>id</td>
<td>vector of subjects id</td>
</tr>
<tr>
<td>X</td>
<td>matrix of covariates in long format</td>
</tr>
<tr>
<td>Y</td>
<td>matrix of responses in long format</td>
</tr>
</tbody>
</table>

**Value**

XX  array of covariates (n x TT x nc)
YY  array of responses (n x TT x r)

**Author(s)**

Francesco Bartolucci, Silvia Pandolfi, University of Perugia (IT), http://www.stat.unipg.it/bartolucci

**Examples**

```r
# Example based on SRHS data
# load SRHS data
data(data_SRHS_long)
data = data_SRHS_long
head(data)
X = cbind(data$gender-1, data$race==2|data$race==3, data$education==4, data$education==5, data$age-50, (data$age-50)^2/100)
Y = data$srhs
res = long2matrices(data$id, X, Y)
```
From data in the long format to data in the wide format

**Description**

Function that transforms data in the long format to data in the wide format.

**Usage**

```r
generateData = function(number, time, sex, y1, y2, y3, y4, y5, y6, y7, y8, y9, y10) {
  data = matrix(c(number, time, sex, y1, y2, y3, y4, y5, y6, y7, y8, y9, y10), ncol = 12)
  data = apply(data, 1, function(x) x[1:3])
  data = data.frame(data)
  return(data)
}

# Example based on generated data

# Load criminal data

data = generateData(1000, 1000, 1:10000, rep(1, 1000), rep(2, 1000),
  rep(3, 1000), rep(4, 1000), rep(5, 1000), rep(6, 1000), rep(7, 1000),
  rep(8, 1000), rep(9, 1000), rep(10, 1000))

# Create data in the long format

data_long = data.frame(number = data[, 1],
  time = data[, 2],
  sex = data[, 3],
  y1 = data[, 4],
  y2 = data[, 5],
  y3 = data[, 6],
  y4 = data[, 7],
  y5 = data[, 8],
  y6 = data[, 9],
  y7 = data[, 10],
  y8 = data[, 11],
  y9 = data[, 12])

# Transform data from long format to wide format

data_wide = long2wide(data_long, nameid = "number", namet = "time",
  colx = c("sex", "y1", "y2", "y3", "y4", "y5", "y6", "y7", "y8", "y9", "y10"),
  coly = c("y1", "y2", "y3", "y4", "y5", "y6", "y7", "y8", "y9", "y10"),
  aggr = TRUE, full = 0)
```

**Arguments**

- `data`: matrix of data
- `nameid`: name of the id column
- `namet`: name of the t column
- `colx`: vector of the names of the columns of the covariates
- `coly`: vector of the names of the columns of the responses
- `aggr`: if wide aggregated format is required
- `full`: number to use for missing data

**Value**

- `listid`: list of id for every unit
- `listt`: list of the time occasions
- `data_wide`: data in wide format
- `XX`: array of the covariates
- `YY`: array of the responses
- `freq`: vector of the corresponding frequencies

**Author(s)**

Francesco Bartolucci, Silvia Pandolfi, University of Perugia (IT), http://www.stat.unipg.it/bartolucci

**Examples**

```r
# Example based on generated data

# Load criminal data

data = generateData(1000, 1000, 1:10000, rep(1, 1000), rep(2, 1000),
  rep(3, 1000), rep(4, 1000), rep(5, 1000), rep(6, 1000), rep(7, 1000),
  rep(8, 1000), rep(9, 1000), rep(10, 1000))

# Create data in the long format

data_long = data.frame(number = data[, 1],
  time = data[, 2],
  sex = data[, 3],
  y1 = data[, 4],
  y2 = data[, 5],
  y3 = data[, 6],
  y4 = data[, 7],
  y5 = data[, 8],
  y6 = data[, 9],
  y7 = data[, 10],
  y8 = data[, 11],
  y9 = data[, 12])

# Transform data from long format to wide format

data_wide = long2wide(data_long, nameid = "number", namet = "time",
  colx = c("sex", "y1", "y2", "y3", "y4", "y5", "y6", "y7", "y8", "y9", "y10"),
  coly = c("y1", "y2", "y3", "y4", "y5", "y6", "y7", "y8", "y9", "y10"),
  aggr = TRUE, full = 0)
```
marg_param

Compute marginal parametrization

Description

Function that creates matrices C and M for the marginal parametrization of the probability vector for a vector of categorical variables

Usage

marg_param(lev, type)

Arguments

lev vector containing the number of levels of each variable
type vector with elements 'l', 'g', 'c', 'r' indicating the type of logit

Value

C matrix of constrats (the first sum(lev)-length(r) elements are referred to univariate logits)
M marginalization matrix with elements 0 and 1
G corresponding design matrix for the corresponding log-linear model

Author(s)

Francesco Bartolucci, Silvia Pandolfi, University of Perugia (IT), http://www.stat.unipg.it/bartolucci

print.LMbasic

Print the output of LMbasic object

Description

Given the output from LMbasic, it is written in a readable form

Usage

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

Arguments

x output from LMbasic
...

further arguments passed to or from other methods
print.LMmanifest

Author(s)
Francesco Bartolucci, Silvia Pandolfi, University of Perugia (IT), http://www.stat.unipg.it/bartolucci

print.LMlatent

Description
Given the output from LMlatent, it is written in a readable form

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

Arguments
x output from LMlatent
... further arguments passed to or from other methods

Author(s)
Francesco Bartolucci, Silvia Pandolfi, University of Perugia (IT), http://www.stat.unipg.it/bartolucci

print.LMmanifest

Description
Given the output from LMmanifest, it is written in a readable form

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

Arguments
x output from LMmanifest
... further arguments passed to or from other methods

Author(s)
Francesco Bartolucci, Silvia Pandolfi, University of Perugia (IT), http://www.stat.unipg.it/bartolucci
**print.LMmixed**

*Print the output of LMmixed object*

### Description

Given the output from LMmixed, it is written in a readable form.

### Usage

```r
## S3 method for class 'LMmixed'
print(x, ...)
```

### Arguments

- `x`: output from LMmixed
- `...`: further arguments passed to or from other methods

### Author(s)

Francesco Bartolucci, Silvia Pandolfi, University of Perugia (IT), http://www.stat.unipg.it/bartolucci

---

**prob_multilogit**

*Compute multinomial probabilities*

### Description

The function computes multinomial probabilities (internal function).

### Usage

```r
prob_multilogit(Xdis, be, label, fort=TRUE, der=FALSE)
```

### Arguments

- `Xdis`: array of all covariates (two- or three-dimensional)
- `be`: initial value of the parameter vector
- `label`: label associated to every covariate configuration
- `fort`: to use fortran routines when possible
- `der`: to compute derivatives
Value

- \( P \) estimated matrix of probabilities
- \( P_{\text{dis}} \) estimated matrix of distinct probabilities
- \( dP \) derivatives of the estimated matrix of probabilities
- \( dP_{\text{dis}} \) derivatives of the estimated matrix of distinct probabilities

Author(s)

Francesco Bartolucci, Silvia Pandolfi - University of Perugia (IT)

prob_post_cov  Compute posterior probabilities.

Description

Function that uses backward recursion to compute posterior probabilities (internal function).

Usage

\[
\text{prob_post_cov}(S, yv, Psi, Piv, PI, Phi, L, pv, \text{der=}FALSE, \text{fort=}TRUE, \\
\quad d1Phi=NULL, d1Piv=NULL, d1PI=NULL, d1L=NULL, d1L2=NULL, d1pv=NULL)
\]

Arguments

- \( S \) matrix of distinct response configurations
- \( yv \) corresponding vector of frequencies
- \( Psi \) conditional response probabilities
- \( Piv \) initial probability matrix
- \( PI \) transition probability matrices
- \( Phi \) matrix of the conditional probabilities of the observed response configurations
- \( L \) matrix of the forward probabilities
- \( pv \) vector of marginal probabilities
- \( \text{der} \) to compute derivatives
- \( \text{fort} \) to use fortran routine when possible
- \( d1Phi \) matrix of derivatives of the log-conditional probabilities of the observed response configurations
- \( d1Piv \) matrix of derivatives of the logarithm of the initial probabilities
- \( d1PI \) matrix of derivatives of the logarithm of the transition probabilities
- \( d1L \) matrix of derivatives of the log-forward probabilities
- \( d1L2 \) matrix of second derivatives of the log-forward probabilities
- \( d1pv \) matrix of derivatives of the log-marginal probabilities
**prod_array**

**Value**
- **U**: array containing the posterior distribution of the latent states for each response configuration and each pair of consecutive time occasions
- **V**: array containing the posterior distribution of the latent states for each response configuration and time occasion
- **d1U**: matrix of derivatives of the logarithm of U
- **d1V**: matrix of derivatives of the logarithm of V

**Author(s)**
Francesco Bartolucci, Silvia Pandolfi, University of Perugia (IT), http://www.stat.unipg.it/bartolucci

**Description**
Function that compute the product of each matrix in X by the vector y (internal function).

**Usage**

```r
prod_array(X, y)
```

**Arguments**
- **X**: a given array
- **y**: a given vector

**Value**
- **Z**: the resulting matrix

**Author(s)**
Francesco Bartolucci, Silvia Pandolfi, University of Perugia (IT), http://www.stat.unipg.it/bartolucci
**Recursions used by est_lm_cov_manifest**

### Description

Implementation of the forward recursions to compute posterior distribution of the latent states (internal function).

### Usage

```r
rec1(Pio, las, PI)
```

### Arguments

- **Pio**: matrix of manifest probabilities
- **las**: stationary initial probability
- **PI**: transition probability matrices

### Value

- **Q**: matrices of posterior probabilities

### Author(s)

Francesco Bartolucci, Silvia Pandolfi, University of Perugia (IT), http://www.stat.unipg.it/bartolucci

### References


---

**Recursions used by est_lm_cov_manifest**

### Description

Implementation of the backward recursions to compute posterior distribution of the latent states (internal function).

### Usage

```r
rec3(Q, PI, Pio, pim)
```
Arguments

- Q: posterior probabilities from the forward recursion
- PI: transition probability matrices
- Pio: matrix of manifest probabilities
- pim: vector of marginal probabilities

Value

- U: array containing the posterior distribution of the latent states for each response configuration and time occasion
- V: matrix containing the posterior distribution of the latent states

Author(s)

Francesco Bartolucci, Silvia Pandolfi - University of Perugia (IT)

References


Recurisions used by est_lm_basic

Description

Implementation of the recursions to compute manifest probability of the responses and posterior distribution of the latent states (internal function).

Usage

recursions(S, yv, Psi, piv, Pi, k, lth, Am, Bm, Cm, b, mod)

Arguments

- S: matrix of distinct response configurations
- yv: corresponding vector of frequencies
- Psi: matrix of conditional response probabilities
- piv: initial probability vector
- Pi: transition probability matrices
- k: number of latent states
- lth: internal argument
- Am: internal argument
Description

Function that creates a matrix with the combination of all possible row vectors with 't' elements equal to 1 and 'J-t' elements equal to 0. If 't' is NULL, the function generates all the possible combinations of vectors of length 'J' with elements (1,0).

Usage

sq(J, t=NULL)

Arguments

J an integer
t an integer

Value

M the resulting matrix
**stationary**

**Author(s)**
Francesco Bartolucci, Silvia Pandolfi - University of Perugia (IT)

---

**Description**
Function that computes the derivatives of the log-likelihood of a stationary model (internal function).

**Usage**
stationary(tau, k, G2, IPI)

**Arguments**
- **tau**: regression parameters
- **k**: number of latent states
- **G2**: internal argument
- **IPI**: index of the transition matrix elements

**Value**
- **d0**: first derivatives of the log-likelihood
- **d1**: second derivatives of the log-likelihood

---

**summary.LMbasic**

**Print the output of LMbasic object**

---

**Description**
Given the output from LMbasic, it is written in a readable form

**Usage**
```r
## S3 method for class 'LMbasic'
summary(object, ...)
```
Arguments

object  output from LMbasic
...     further arguments passed to or from other methods

Value

table  summary of all the results

Author(s)

Francesco Bartolucci, Silvia Pandolfi, University of Perugia (IT), http://www.stat.unipg.it/bartolucci

summary.LMlatent

 Print the output of LMlatent object

Description

Given the output from LMlatent, it is written in a readable form

Usage

## S3 method for class 'LMlatent'
summary(object, ...)

Arguments

object  output from LMlatent
...     further arguments passed to or from other methods

Value

table  summary of all the results

Author(s)

Francesco Bartolucci, Silvia Pandolfi, University of Perugia (IT), http://www.stat.unipg.it/bartolucci
summary.LMmanifest | Print the output of LMmanifest object

**Description**

Given the output from LMmanifest, it is written in a readable form

**Usage**

```r
## S3 method for class 'LMmanifest'
summary(object, ...)
```

**Arguments**

- `object`: output from LMmanifest
- `...`: further arguments passed to or from other methods

**Value**

- `table`: summary of all the results

**Author(s)**

Francesco Bartolucci, Silvia Pandolfi, University of Perugia (IT), http://www.stat.unipg.it/bartolucci

summary.LMmixed | Print the output of LMmixed object

**Description**

Given the output from LMmixed, it is written in a readable form

**Usage**

```r
## S3 method for class 'LMmixed'
summary(object, ...)
```

**Arguments**

- `object`: output from LMmixed
- `...`: further arguments passed to or from other methods
trans_par

Value

table summary of all the results

Author(s)

Francesco Bartolucci, Silvia Pandolfi, University of Perugia (IT), http://www.stat.unipg.it/bartolucci

---

trans_par Convert matrix parametrization

Description

Function that converts matrix parametrization (internal function).

Usage

trans_par(par, lev, k, sup, G2, IPI, mod)

Arguments

par regression parameters
lev vector containing the number of levels of each variable
k number of latent states
sup vectors of support points
G2 internal argument
IPI internal argument
mod model (0 = LM with stationary transition, 1 = finite mixture)

Value

la vector of initial probabilities
PI transition matrix
rho parameter vector for AR
si sigma of the AR process
par regression parameters
l rho Fisher transformation of the autocorrelation coefficient
tau regression parameters

Author(s)

Francesco Bartolucci, Silvia Pandolfi - University of Perugia (IT)
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