Package 'lsirm12pl'

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Type Package

Title Latent Space Item Response Model

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Description Analysis of dichotomous and continuous response data using latent factor by both 1PL LSIRM and 2PL LSIRM as described in Jeon et al. (2021) <doi:10.1007/s11336-021-09762-5>. It includes original 1PL LSIRM and 2PL LSIRM provided for binary response data and its extension for continuous response data. Bayesian model selection with spike-and-slab prior and method for dealing data with missing value under missing at random, missing completely at random are also supported. Various diagnostic plots are available to inspect the latent space and summary of estimated parameters.

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Imports Rcpp (>= 1.0.5), MCMCpack, ggplot2, GPArotation, dplyr, grDevices

LinkingTo Rcpp, RcppArmadillo

Encoding UTF-8

RoxygenNote 7.1.2

Suggests knitr, testthat

Depends R (>= 3.1.0)

LazyData true

NeedsCompilation yes

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R topics documented:

BFPT *Big Five Personality Test*

Description

A dataset containing the result of personality test for 50 questions from 1,000 random sampled people.

Usage

```
data(BFPT)
```

Format

A matrix with 1,015,341 rows and 50 columns.

Details

A dataset collected in 2016-2018 through an interactive on-line personality test, containing the result of personality test for 50 questions. 1,000 people are random sampled from the original dataset containing 1,015,341 people. The scale is labeled as 1=Disagree, 3=Neutral and 5=Agree.

Source

https://www.kaggle.com/tunguz/big-five-personality-test

intrm1pl *1pl LSIRM model with multiplicative effect*

Description

intrm1pl integrates functions related to 1pl LSIRM with multiplicative effect. Different missing mechanism can be specified.

Usage

```
intrm1pl(data, missing_data = NA, ...)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
missing_data	The assumed missing type. One of NA, "mar" and "mcar". Default uses NA.
...	Additional arguments for the corresponding function.

Value

intrm1pl returns an object of list. See corresponding function.

See Also

intrm1pl_o, intrm1pl_mar, intrm1pl_mcar

intrm1pl_mar *1pl LSIRM model using multiplicative effect for missing at random data.*

Description

intrm1pl_mar is used to fit 1pl LSIRM model using multiplicative effect in incomplete data under missing at random assumption. intrm1pl_mar factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds multiplicative effect in a latent space, while considering the missing element under the assumption of missing at random. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
intrm1pl_mar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_delta = 1,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_delta = 0,
  pr_sd_delta = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  missing = 99
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_delta	Numeric; jumping rule of the proposal density for delta default value is 1.0.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_delta	Numeric; mean of normal prior for delta. default value is 0.
pr_sd_delta	Numeric; standard deviation of normal prior for delta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.

pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

intrm1pl_mar models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j in the shared metric space:

$$logit(P(Y_{j,i} = 1|\theta_j, \beta_i, \delta_{j,i})) = \theta_j + \beta_i + \delta_{j,i}$$

The final latent positions of respondents and items are the singular vectors of matrix with its j, i element $\delta_{j,i}$. Under the assumption of missing at random, the model takes the missing element into consideration in the sampling procedure. For the details of missing at random assumption and data augmentation, see References.

Value

intrm1pl_mar returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
delta_estimate	posterior estimation of delta.
imp_estimate	probability of imputating a missing value with 1.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
delta	posterior samples of delta.
imp	imputation for missing Values using posterior samples.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
ls_mean_item	posterior estimation of latent position of item.
ls_mean_respondent	posterior estimation of latent position of respondent.
ls_mean_lambda	posterior estimation lambda. The singular value of the decomposition.
ls_respondent	posterior samples of latent positon of respondent.
ls_item	posterior samples of latent positon of item.
ls_lambda	posterior samples of lambda which is singular value of decomposition.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5), ncol=10, nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2), ncol=10, nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- intrm1pl_mar(data)

# The code following can achieve the same result.
lsirm_result <- intrm1pl(data, missing_data = 'mar')
```

`intrm1pl_mcar` *1pl LSIRM model with multiplicative effect for missing completely at random data.*

Description

intrm1pl_mcar is used to fit LSIRM model with 1pl using multiplicative effect in incomplete data under the missing completely at random assumption. intrm1pl_mcar factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds multiplicative effect in a latent space, while ignoring the missing element under the assumption of missing completely at random. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
intrm1pl_mcar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_delta = 1,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_delta = 0,
  pr_sd_delta = 1,
```

```
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  missing = 99
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_delta	Numeric; jumping rule of the proposal density for delta default value is 1.0.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_delta	Numeric; mean of normal prior for delta. default value is 0.
pr_sd_delta	Numeric; standard deviation of normal prior for delta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

intrm1pl_mcar models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j in the shared metric space:

$$logit(P(Y_{j,i} = 1|\theta_j, \beta_i, \delta_{j,i})) = \theta_j + \beta_i + \delta_{j,i}$$

The final latent positions of respondents and items are the singular vectors of matrix with its j, i element $\delta_{j,i}$. Under the assumption of missing completely at random, the model ignores the missing element in doing inference. For the details of missing completely at random assumption and data augmentation, see References.

Value

intrm1pl_mcar returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
delta_estimate	posterior estimation of delta.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
delta	posterior samples of delta.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
ls_mean_item	posterior estimation of latent position of item.
ls_mean_respondent	posterior estimation of latent position of respondent.
ls_mean_lambda	posterior estimation lambda. The singular value of the decomposition.
ls_respondent	posterior samples of latent positon of respondent.
ls_item	posterior samples of latent positon of item.
ls_lambda	posterior samples of lambda which is singular value of decomposition.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- intrm1pl_mcar(data)

# The code following can achieve the same result.
lsirm_result <- intrm1pl(data, missing_data = 'mcar')
```

`intrm1pl_normal` *1pl LSIRM model with normal likelihood using multiplicative effect*

Description

intrm1pl_normal integrates all functions related to 1pl LSIRM model with normal likelihood using multiplicative effect.

Usage

```
intrm1pl_normal(data, missing_data = NA, ...)
```

Arguments

`data`	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
`missing_data`	The assumed missing type. One of NA, "mar", and "mcar". Default uses NA.
`...`	Additional arguments for the corresponding function.

Value

`lsirm1pl_normal` returns an object of list. See corresponding function.

See Also

`intrm1pl_normal_o`, `intrm1pl_normal_mar`, `intrm1pl_normal_mcar`

`intrm1pl_normal_mar` *1pl LSIRM model with normal likelihood using multiplicative effect for missing at random data.*

Description

intrm1pl_normal_mar is used to fit LSIRM model for continuous variable with 1pl using multiplicative effect in incomplete data under missing at random assumption. intrm1pl_normal_mar factorizes continuous item response matrix into column-wise item effect, row-wise respondent effect and further embeds multiplicative effect in a latent space, while considering the missing element under the assumption of missing at random. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
intrm1pl_normal_mar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_delta = 1,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_delta = 0,
  pr_sd_delta = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001,
  missing = 99
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_delta	Numeric; jumping rule of the proposal density for delta default value is 1.0.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_delta	Numeric; mean of normal prior for delta. default value is 0.
pr_sd_delta	Numeric; standard deviation of normal prior for delta. default value is 1.0.

pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

intrm1pl_normal_mar models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j in the shared metric space:

$$Y_{j,i} = \theta_j + \beta_i + \delta_{j,i} + e_{j,i}$$

where the error $e_{j,i} \sim N(0, \sigma^2)$. The final latent positions of respondents and items are the singular vectors of matrix with its j, i element $\delta_{j,i}$. Under the assumption of missing at random, the model takes the missing element into consideration in the sampling procedure. For the details of missing at random assumption and data augmentation, see References.

Value

intrm1pl_normal_mar returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
sigma_estimate	posterior estimation of standard deviation.
delta_estimate	posterior estimation of delta.
imp_estimate	estimation of imputing missing values.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
sigma	posterior samples of standard deviation.
delta	posterior samples of delta.
imp	imputation for missing Values using posterior samples.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
ls_mean_item	posterior estimation of latent position of item.
ls_mean_respondent	posterior estimation of latent position of respondent.

ls_mean_lambda	posterior estimation lambda. The singular value of the decomposition.
ls_respondent	posterior samples of latent positon of respondent.
ls_item	posterior samples of latent positon of item.
ls_lambda	posterior samples of lambda which is singular value of decomposition.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons.

Examples

```
# generate example (continuous) item response matrix
data     <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- intrm1pl_normal_mar(data)

# The code following can achieve the same result.
lsirm_result <- intrm1pl_normal(data, missing_data = 'mar')
```

---

intrm1pl_normal_mcar *1pl LSIRM model with normal likelihood using multiplicative effect for missing completely at random data.*

Description

intrm1pl_normal_mcar is used to fit LSIRM model for continuous variable with 1pl using multiplicative effect in incomplete data under missing completely at random assumption.

intrm1pl_normal_mcar factorizes continuous item response matrix into column-wise item effect, row-wise respondent effect and further embeds multiplicative effect in a latent space, while ignoring the missing element under the assumption of missing completely at random. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
intrm1pl_normal_mcar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
```

```
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_delta = 1,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_delta = 0,
  pr_sd_delta = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001,
  missing = 99
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_delta	Numeric; jumping rule of the proposal density for delta default value is 1.0.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_delta	Numeric; mean of normal prior for delta. default value is 0.
pr_sd_delta	Numeric; standard deviation of normal prior for delta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

`intrm1pl_normal_mcar` models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j in the shared metric space:

$$Y_{j,i} = \theta_j + \beta_i + \delta_{j,i} + e_{j,i}$$

where the error $e_{j,i} \sim N(0, \sigma^2)$. The final latent positions of respondents and items are the singular vectors of matrix with its j, i element $\delta_{j,i}$. Under the assumption of missing completely at random, the model ignores the missing element in doing inference. For the details of missing completely at random assumption and data augmentation, see References.

Value

`intrm1pl_normal_mcar` returns an object of list containing the following components:

`beta_estimate`	posterior estimation of beta.
`theta_estimate`	posterior estimation of theta.
`sigma_theta_estimate`	posterior estimation of standard deviation of theta.
`sigma_estimate`	posterior estimation of standard deviation.
`delta_estimate`	posterior estimation of delta.
`beta`	posterior samples of beta.
`theta`	posterior samples of theta.
`theta_sd`	posterior samples of standard deviation of theta.
`sigma`	posterior samples of standard deviation.
`delta`	posterior samples of delta.
`accept_beta`	accept ratio of beta.
`accept_theta`	accept ratio of theta.
`ls_mean_item`	posterior estimation of latent position of item.
`ls_mean_respondent`	posterior estimation of latent position of respondent.
`ls_mean_lambda`	posterior estimation lambda. The singular value of the decomposition.
`ls_respondent`	posterior samples of latent positon of respondent.
`ls_item`	posterior samples of latent positon of item.
`ls_lambda`	posterior samples of lambda which is singular value of decomposition.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons.

Examples

```
# generate example (continuous) item response matrix
data     <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- intrm1pl_normal_mcar(data)

# The code following can achieve the same result.
lsirm_result <- intrm1pl_normal(data, missing_data = 'mcar')
```

`intrm1pl_normal_o` *1pl LSIRM model with normal likelihood using multiplicative effect.*

Description

intrm1pl_normal_o is used to fit LSIRM model with 1pl for continuous variable using multiplicative effect. intrm1pl_normal_o factorizes continuous item response matrix into column-wise item effect, row-wise respondent effect and further embeds multiplicative effect in a latent space. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
intrm1pl_normal_o(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_delta = 1,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_delta = 0,
  pr_sd_delta = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_delta	Numeric; jumping rule of the proposal density for delta default value is 1.0.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_delta	Numeric; mean of normal prior for delta. default value is 0.
pr_sd_delta	Numeric; standard deviation of normal prior for delta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.

Details

intrm1pl_normal_o models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j in the shared metric space:

$$Y_{j,i} = \theta_j + \beta_i + \delta_{j,i} + e_{j,i}$$

where the error $e_{j,i} \sim N(0, \sigma^2)$. The final latent positions of respondents and items are the singular vectors of matrix with its j, i element $\delta_{j,i}$.

Value

intrm1pl_normal_o returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.

`sigma_theta_estimate` posterior estimation of standard deviation of theta.

`sigma_estimate` posterior estimation of standard deviation.

`delta_estimate` posterior estimation of delta.

`beta` posterior samples of beta.

`theta` posterior samples of theta.

`theta_sd` posterior samples of standard deviation of theta.

`sigma` posterior samples of standard deviation.

`delta` posterior samples of delta.

`accept_beta` accept ratio of beta.

`accept_theta` accept ratio of theta.

`ls_mean_item` posterior estimation of latent position of item.

`ls_mean_respondent` posterior estimation of latent position of respondent.

`ls_mean_lambda` posterior estimation lambda which is singular value of decomposition.

`ls_respondent` posterior samples of latent positon of respondent.

`ls_item` posterior samples of latent positon of item.

`ls_lambda` posterior samples of lambda which is singular value of decomposition.

Examples

```
# generate example (continuous) item response matrix
data     <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)

lsirm_result <- intrm1pl_normal_o(data)

# The code following can achieve the same result.
lsirm_result <- intrm1pl_normal(data)
```

`intrm1pl_o` *1pl LSIRM model using multiplicative effect*

Description

intrm1pl_o is used to fit 1pl LSIRM model using multiplicative effect. intrm1pl_o factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds multiplicative effect in a latent space. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
intrm1pl_o(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_delta = 1,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_delta = 0,
  pr_sd_delta = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_delta	Numeric; jumping rule of the proposal density for delta default value is 1.0.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_delta	Numeric; mean of normal prior for delta. default value is 0.
pr_sd_delta	Numeric; standard deviation of normal prior for delta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.

Details

`intrm1pl_o` models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j in the shared metric space:

$$logit(P(Y_{j,i} = 1|\theta_j, \beta_i, \delta_{j,i})) = \theta_j + \beta_i + \delta_{j,i}$$

The final latent positions of respondents and items are the singular vectors of matrix with its j, i element $\delta_{j,i}$.

Value

`intrm1pl_o` returns an object of list containing the following components:

`beta_estimate`	posterior estimation of beta.
`theta_estimate`	posterior estimation of theta.
`sigma_theta_estimate`	posterior estimation of standard deviation of theta.
`delta_estimate`	posterior estimation of delta.
`beta`	posterior samples of beta.
`theta`	posterior samples of theta.
`theta_sd`	posterior samples of standard deviation of theta.
`delta`	posterior samples of delta.
`accept_beta`	accept ratio of beta.
`accept_theta`	accept ratio of theta.
`ls_mean_item`	posterior estimation of latent position of item.
`ls_mean_respondent`	posterior estimation of latent position of respondent.
`ls_mean_lambda`	posterior estimation lambda. The singular value of the decomposition.
`ls_respondent`	posterior samples of latent positon of respondent.
`ls_item`	posterior samples of latent positon of item.
`ls_lambda`	posterior samples of lambda which is singular value of decomposition.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5), ncol=10, nrow=50)

lsirm_result <- intrm1pl_o(data)

# The code following can achieve the same result.
lsirm_result <- intrm1pl(data)
```

intrm2pl *2pl LSIRM model using multiplicative effect*

Description

intrm2pl integrates all functions related to 2pl LSIRM using multiplicative effect.

Usage

```
intrm2pl(data, missing_data = NA, ...)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
missing_data	The assumed missing type. One of NA, "mar" and "mcar". Default uses NA.
...	Additional arguments for the corresponding function.

Value

intrm2pl returns an object of list. See corresponding function.

See Also

intrm2pl_o, intrm2pl_mar, intrm2pl_mcar

intrm2pl_mar *2pl LSIRM model using multiplicative effect for missing at random data.*

Description

intrm2pl_mar is used to fit 2pl LSIRM model using multiplicative effect in incomplete data under missing at random assumption. intrm2pl_mar factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds multiplicative effect in a latent space, while considering the missing element under the assumption of missing at random. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
intrm2pl_mar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_delta = 1,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_delta = 0,
  pr_sd_delta = 1,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  missing = 99
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha. default value is 1.0.
jump_delta	Numeric; jumping rule of the proposal density for delta default value is 1.0.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_delta	Numeric; mean of normal prior for delta. default value is 0.

pr_sd_delta	Numeric; standard deviation of normal prior for delta. default value is 1.0.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; mean of normal prior for beta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

intrm2pl_mar models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j in the shared metric space. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$logit(P(Y_{j,i} = 1|\theta_j, \alpha_i, \beta_i, \delta_{j,i})) = \theta_j * \alpha_i + \beta_i + \delta_{j,i}$$

The final latent positions of respondents and items are the singular vectors of matrix with its j, i element $\delta_{j,i}$. Under the assumption of missing at random, the model takes the missing element into consideration in the sampling procedure. For the details of missing at random assumption and data augmentation, see References.

Value

intrm2pl_mar returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
delta_estimate	posterior estimation of delta.
alpha_estimate	posterior estimation of alpha.
imp_estimate	probability of imputating a missing value with 1.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
delta	posterior samples of delta.
alpha	posterior samples of alpha.
imp	imputation for missing Values using posterior samples.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_alpha	accept ratio of alpha.
ls_mean_item	posterior estimation of latent position of item.

`ls_mean_respondent` posterior estimation of latent position of respondent.

`ls_mean_lambda` posterior estimation lambda. The singular value of the decomposition.

`ls_respondent` posterior samples of latent positon of respondent.

`ls_item` posterior samples of latent positon of item.

`ls_lambda` posterior samples of lambda which is singular value of decomposition.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5), ncol=10, nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2), ncol=10, nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- intrm2pl_mar(data)

# The code following can achieve the same result.
lsirm_result <- intrm2pl(data, missing_data = 'mar')
```

`intrm2pl_mcar` *2pl LSIRM model using multiplicative effect for missing completely at random data.*

Description

intrm2pl_mcar is used to fit 2pl LSIRM model using multiplicative effect in incomplete data under missing completely at random assumption. intrm2pl_mcar factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds multiplicative effect in a latent space, while ignoring the missing element under the assumption of missing completely at random. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
intrm2pl_mcar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_delta = 1,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_delta = 0,
  pr_sd_delta = 1,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  missing = 99
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha. default value is 1.0.
jump_delta	Numeric; jumping rule of the proposal density for delta default value is 1.0.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_delta	Numeric; mean of normal prior for delta. default value is 0.

pr_sd_delta	Numeric; standard deviation of normal prior for delta. default value is 1.0.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; mean of normal prior for beta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

intrm2pl_mcar models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j in the shared metric space. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$logit(P(Y_{j,i} = 1|\theta_j, \alpha_i, \beta_i, \delta_{j,i})) = \theta_j * \alpha_i + \beta_i + \delta_{j,i}$$

The final latent positions of respondents and items are the singular vectors of matrix with its j, i element $\delta_{j,i}$. Under the assumption of missing completely at random, the model ignores the missing element in doing inference. For the details of missing completely at random assumption and data augmentation, see References.

Value

intrm2pl_mcar returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
delta_estimate	posterior estimation of delta.
alpha_estimate	posterior estimation of alpha.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
delta	posterior samples of delta.
alpha	posterior samples of alpha.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_alpha	accept ratio of alpha.
ls_mean_item	posterior estimation of latent position of item.
ls_mean_respondent	posterior estimation of latent position of respondent.
ls_mean_lambda	posterior estimation lambda. The singular value of the decomposition.
ls_respondent	posterior samples of latent positon of respondent.
ls_item	posterior samples of latent positon of item.
ls_lambda	posterior samples of lambda which is singular value of decomposition.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5), ncol=10, nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2), ncol=10, nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- intrm2pl_mcar(data)

# The code following can achieve the same result.
lsirm_result <- intrm2pl(data, missing_data = 'mcar')
```

`intrm2pl_normal` *2pl LSIRM model with normal likelihood using multiplicative effect*

Description

lsirm2pl_normal integrates all functions related to 2pl LSIRM with normal likelihood.

Usage

```
intrm2pl_normal(data, missing_data = NA, ...)
```

Arguments

`data`	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
`missing_data`	The assumed missing type. One of NA, "mar", and "mcar". Default uses NA.
`...`	Additional arguments for the corresponding function.

Value

`lsirm2pl_normal` returns an object of list. See corresponding function.

See Also

`intrm2pl_normal_o`, `intrm2pl_normal_mar`, `intrm2pl_normal_mcar`

`intrm2pl_normal_mar` *2pl LSIRM model with normal likelihood using multiplicative effect for missing at random data.*

Description

intrm2pl_normal_mar is used to fit 2pl LSIRM model for continuous variable using multiplicative effect in incomplete data under missing at random assumption. intrm2pl_normal_mar factorizes continuous item response matrix into column-wise item effect, row-wise respondent effect and further embeds multiplicative effect in a latent space, while considering the missing element under the assumption of missing at random. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
intrm2pl_normal_mar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_delta = 1,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_delta = 0,
  pr_sd_delta = 1,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001,
  missing = 99
)
```

Arguments

`data`	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.

ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha. default value is 1.0.
jump_delta	Numeric; jumping rule of the proposal density for delta default value is 1.0.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_delta	Numeric; mean of normal prior for delta. default value is 0.
pr_sd_delta	Numeric; standard deviation of normal prior for delta. default value is 1.0.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; mean of normal prior for beta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

intrm2pl_normal_mar models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j in the shared metric space. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$Y_{j,i} = \theta_j * \alpha_i + \beta_i + \delta_{j,i} + e_{j,i}$$

where the error $e_{j,i} \sim N(0, \sigma^2)$. The final latent positions of respondents and items are the singular vectors of matrix with its j, i element $\delta_{j,i}$. Under the assumption of missing at random, the model takes the missing element into consideration in the sampling procedure. For the details of missing at random assumption and data augmentation, see References.

Value

intrm2pl_normal_mar returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
sigma_estimate	posterior estimation of standard deviation.
delta_estimate	posterior estimation of delta.
alpha_estimate	posterior estimation of alpha.
imp_estimate	estimation of imputing missing values.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
sigma	posterior samples of standard deviation.
delta	posterior samples of delta.
alpha	posterior samples of alpha.
imp	imputation for missing Values using posterior samples.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
ls_mean_item	posterior estimation of latent position of item.
ls_mean_respondent	posterior estimation of latent position of respondent.
ls_mean_lambda	posterior estimation lambda. The singular value of the decomposition.
ls_respondent	posterior samples of latent positon of respondent.
ls_item	posterior samples of latent positon of item.
ls_lambda	posterior samples of lambda which is singular value of decomposition.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons.

Examples

```
# generate example (continuous) item response matrix
data     <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99
```

```
lsirm_result <- intrm2pl_normal_mar(data)

# The code following can achieve the same result.
lsirm_result <- intrm2pl_normal(data, missing_data = 'mar')
```

`intrm2pl_normal_mcar` *LSIRM model with normal likelihood and 2pl using multiplicative effect for missing completely at random data.*

Description

intrm2pl_normal_mar is used to fit 2pl LSIRM model for continuous variable using multiplicative effect in incomplete data under missing completely at random assumption. intrm2pl_normal_mar factorizes continuous item response matrix into column-wise item effect, row-wise respondent effect and further embeds multiplicative effect in a latent space, while considering the missing element under the assumption of missing completely at random. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
intrm2pl_normal_mcar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_delta = 1,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_delta = 0,
  pr_sd_delta = 1,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001,
  missing = 99
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha. default value is 1.0.
jump_delta	Numeric; jumping rule of the proposal density for delta default value is 1.0.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_delta	Numeric; mean of normal prior for delta. default value is 0.
pr_sd_delta	Numeric; standard deviation of normal prior for delta. default value is 1.0.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; mean of normal prior for beta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

intrm2pl_normal_mcar models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j in the shared metric space. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$Y_{j,i} = \theta_j * \alpha_i + \beta_i + \delta_{j,i} + e_{j,i}$$

where the error $e_{j,i} \sim N(0, \sigma^2)$. The final latent positions of respondents and items are the singular vectors of matrix with its j, i element $\delta_{j,i}$. Under the assumption of missing completely at random, the model ignores the missing element in doing inference. For the details of missing completely at random assumption and data augmentation, see References.

Value

intrm2pl_normal_mcar returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
sigma_estimate	posterior estimation of standard deviation.
delta_estimate	posterior estimation of delta.
alpha_estimate	posterior estimation of alpha.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
sigma	posterior samples of standard deviation.
delta	posterior samples of delta.
alpha	posterior samples of alpha.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
ls_mean_item	posterior estimation of latent position of item.
ls_mean_respondent	posterior estimation of latent position of respondent.
ls_mean_lambda	posterior estimation lambda. The singular value of the decomposition.
ls_respondent	posterior samples of latent positon of respondent.
ls_item	posterior samples of latent positon of item.
ls_lambda	posterior samples of lambda which is singular value of decomposition.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons.

Examples

```
# generate example (continuous) item response matrix
data     <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- intrm2pl_normal_mcar(data)

# The code following can achieve the same result.
lsirm_result <- intrm2pl_normal(data, missing_data = 'mcar')
```

`intrm2pl_normal_o` *2pl LSIRM model with normal likelihood using multiplicative effect*

Description

intrm2pl_normal_o is used to fit 2pl LSIRM model for continuous variable using multiplicative effect. intrm2pl_normal_o factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds multiplicative effect in a latent space. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
intrm2pl_normal_o(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_delta = 1,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_delta = 0,
  pr_sd_delta = 1,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001
)
```

Arguments

`data`	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
`ndim`	Numeric; dimension of latent space. default value is 2.
`niter`	Numeric; number of iterations to run MCMC sampling. default value is 15000.

nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha default value is 1.0.
jump_delta	Numeric; jumping rule of the proposal density for delta default value is 1.0.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_delta	Numeric; mean of normal prior for delta. default value is 0.
pr_sd_delta	Numeric; standard deviation of normal prior for delta. default value is 1.0.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; standard deviation of normal prior for alpha, default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.

Details

intrm2pl_normal_o models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j in the shared metric space. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$Y_{j,i} = \theta_j * \alpha_i + \beta_i + \delta_{j,i} + e_{j,i}$$

where the error $e_{j,i} \sim N(0, \sigma^2)$. The final latent positions of respondents and items are the singular vectors of matrix with its j, i element $\delta_{j,i}$.

Value

intrm2pl_normal_o returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.

sigma_estimate	posterior estimation of standard deviation.
delta_estimate	posterior estimation of delta.
alpha_estimate	posterior estimation of alpha.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
sigma	posterior samples of standard deviation.
delta	posterior samples of delta.
alpha	posterior samples of alpha.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_alpha	accept ratio of alpha.
ls_mean_item	posterior estimation of latent position of item.
ls_mean_respondent	posterior estimation of latent position of respondent.
ls_mean_lambda	posterior estimation lambda. The singular value of the decomposition.
ls_respondent	posterior samples of latent positon of respondent.
ls_item	posterior samples of latent positon of item.
ls_lambda	posterior samples of lambda which is singular value of decomposition.

Examples

```
# generate example (continuous) item response matrix
data     <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)

lsirm_result <- intrm2pl_normal_o(data)

# The code following can achieve the same result.
lsirm_result <- intrm2pl_normal(data)
```

`intrm2pl_o` *2pl LSIRM model using multiplicative effect*

Description

intrm2pl_o is used to fit 2pl LSIRM model using multiplicative effect. intrm2pl_o factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds multiplicative effect in a latent space. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
intrm2pl_o(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_delta = 1,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_delta = 0,
  pr_sd_delta = 1,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha default value is 1.0.
jump_delta	Numeric; jumping rule of the proposal density for delta default value is 1.0.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_delta	Numeric; mean of normal prior for delta. default value is 0.
pr_sd_delta	Numeric; standard deviation of normal prior for delta. default value is 1.0.

pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; standard deviation of normal prior for alpha. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.

Details

intrm2pl_o models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j in the shared metric space. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j :

$$logit(P(Y_{j,i} = 1|\theta_j, \beta_i, \alpha_i, \delta_{j,i})) = \theta_j * \alpha_i + \beta_i + \delta_{j,i}$$

The final latent positions of respondents and items are the singular vectors of matrix with its j, i element $\delta_{j,i}$.

Value

intrm2pl_o returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
delta_estimate	posterior estimation of delta.
alpha_estimate	posterior estimation of alpha.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
delta	posterior samples of delta.
alpha	posterior samples of alpha.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_alpha	accept ratio of alpha.
ls_mean_item	posterior estimation of latent position of item.
ls_mean_respondent	posterior estimation of latent position of respondent.
ls_mean_lambda	posterior estimation lambda. The singular value of the decomposition..
ls_respondent	posterior samples of latent positon of respondent.
ls_item	posterior samples of latent positon of item.
ls_lambda	posterior samples of lambda which is singular value of decomposition..

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5),ncol=10,nrow=50)

lsirm_result <- intrm2pl_o(data)

# The code following can achieve the same result.
lsirm_result <- intrm2pl(data)
```

`lsirm12pl` *lsirm12pl-package*

Description

Analysis of dichotomous and continuous response data using latent factor by both 1PL LSIRM and 2PL LSIRM

`lsirm1pl` *1pl LSIRM model*

Description

lsirm1pl integrates all functions related to 1pl LSIRM

Usage

```
lsirm1pl(data, spikenslab = FALSE, fixed_gamma = FALSE, missing_data = NA, ...)
```

Arguments

`data`	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
`spikenslab`	Whether to use a model selection approach.
`fixed_gamma`	Whether fix gamma to 1.
`missing_data`	The assumed missing type. One of NA, "mar" and "mcar". Default uses NA.
`...`	Additional arguments for the corresponding function.

Value

`lsirm1pl` returns an object of list. See corresponding function.

Note

If both spikenslab and fixed_gamma are set TRUE, it returns error because both are related to gamma.

See Also

lsirm1pl_o, lsirm1pl_fixed_gamma, lsirm1pl_mar, lsirm1pl_mcar,lsirm1pl_fixed_gamma_mar, lsirm1pl_fixed_gamma_mcar, lsirm1pl_ss, lsirm1pl_mar_ss, lsirm1pl_mcar_ss

---

lsirm1pl_fixed_gamma *1pl LSIRM model fixing gamma to 1.*

Description

lsirm1pl_fixed_gamma is used to fit 1pl LSIRM model with gamma fixed to 1. lsirm1pl_fixed_gamma factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm1pl_fixed_gamma(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.

nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.

Details

lsirm1pl_fixed_gamma models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space:

$$logit(P(Y_{j,i} = 1|\theta_j, \beta_i, z_j, w_i)) = \theta_j + \beta_i - ||z_j - w_i||$$

Value

lsirm1pl_fixed_gamma returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
z_estimate	posterior estimation of z.
w_estimate	posterior estimation of w.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_z	accept ratio of z.
accept_w	accept ratio of w.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5),ncol=10,nrow=50)

lsirm_result <- lsirm1pl_fixed_gamma(data)

# The code following can achieve the same result.
lsirm_result <- lsirm1pl(data, spikenslab = FALSE, fixed_gamma = TRUE)
```

---

lsirm1pl_fixed_gamma_mar

1pl LSIRM model fixing gamma to 1 for missing at random data.

Description

lsirm1pl_fixed_gamma_mar is used to fit LSIRM model with gamma fixed to 1 in incomplete data assumed to be missing at random. lsirm1pl_fixed_gamma_mar factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space, while considering the missing element under the assumption of missing at random. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm1pl_fixed_gamma_mar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  missing = 99
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric; number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

lsirm1pl_fixed_gamma_mar models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space:

$$logit(P(Y_{j,i} = 1|\theta_j, \beta_i, z_j, w_i)) = \theta_j + \beta_i - ||z_j - w_i||$$

Under the assumption of missing at random, the model takes the missing element into consideration in the sampling procedure. For the details of missing at random assumption and data augmentation, see References.

Value

lsirm1pl_fixed_gamma_mar returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.

z_estimate	posterior estimation of z.
w_estimate	posterior estimation of w.
imp_estimate	probability of imputating a missing value with 1.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
imp	imputation for missing Values using posterior samples.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm1pl_fixed_gamma_mar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm1pl(data, spikenslab = FALSE, fixed_gamma = TRUE, missing_data = 'mar')
```

`lsirm1pl_fixed_gamma_mcar` *1pl LSIRM model fixing gamma to 1 for missing completely at random data.*

Description

lsirm1pl_fixed_gamma_mcar is used to fit LSIRM model with gamma fixed to 1 in incomplete data assumed to be missing completely at random. lsirm1pl_fixed_gamma_mcar factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space, while ignoring the missing element under the assumption of missing completely at random. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm1pl_fixed_gamma_mcar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  missing = 99
)
```

Arguments

`data`	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
`ndim`	Numeric; dimension of latent space. default value is 2.
`niter`	Numeric; number of iterations to run MCMC sampling. default value is 15000.
`nburn`	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
`nthin`	Numeric;number of thinning, MCMC iterations to discard. default value is 5.

nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

lsirm1pl_fixed_gamma_mcar models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space:

$$logit(P(Y_{j,i} = 1|\theta_j, \beta_i, z_j, w_i)) = \theta_j + \beta_i - ||z_j - w_i||$$

Under the assumption of missing completely at random, the model ignores the missing element in doing inference. For the details of missing completely at random assumption and data augmentation, see References.

Value

lsirm1pl_fixed_gamma_mcar returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
z_estimate	posterior estimation of z.
w_estimate	posterior estimation of w.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.

accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm1pl_fixed_gamma_mcar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm1pl(data, spikenslab = FALSE, fixed_gamma = TRUE, missing_data = 'mcar')
```

---

lsirm1pl_mar *1pl LSIRM model for missing at random data.*

Description

lsirm1pl_mar is used to fit 1pl LSIRM model in incomplete data assumed to be missing at random. lsirm1pl_mar factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space, while considering the missing element under the assumption of missing at random. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm1pl_mar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
```

```
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_gamma = 0.025,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_gamma = 0.5,
  pr_sd_gamma = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  missing = 99
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 0.025.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_gamma	Numeric; mean of log normal prior for gamma. default value is 0.5.
pr_sd_gamma	Numeric; standard deviation of log normal prior for gamma. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

`lsirm1pl_mar` models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space, with γ represents the weight of the distance term:

$$logit(P(Y_{j,i} = 1|\theta_j, \beta_i, \gamma, z_j, w_i)) = \theta_j + \beta_i - \gamma||z_j - w_i||$$

Under the assumption of missing at random, the model takes the missing element into consideration in the sampling procedure. For the details of missing at random assumption and data augmentation, see References.

Value

`lsirm1pl_mar` returns an object of list containing the following components:

`beta_estimate`	posterior estimation of beta.
`theta_estimate`	posterior estimation of theta.
`sigma_theta_estimate`	posterior estimation of standard deviation of theta.
`gamma_estimate`	posterior estimation of gamma.
`z_estimate`	posterior estimation of z.
`w_estimate`	posterior estimation of w.
`imp_estimate`	probability of imputating a missing value with 1.
`beta`	posterior samples of beta.
`theta`	posterior samples of theta.
`theta_sd`	posterior samples of standard deviation of theta.
`gamma`	posterior samples of gamma.
`z`	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
`w`	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
`imp`	imputation for missing Values using posterior samples.
`accept_beta`	accept ratio of beta.
`accept_theta`	accept ratio of theta.
`accept_z`	accept ratio of z.
`accept_w`	accept ratio of w.
`accept_gamma`	accept ratio of gamma.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm1pl_mar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm1pl(data, spikenslab = FALSE, fixed_gamma = FALSE, missing_data ='mar')
```

`lsirm1pl_mar_ss` *1pl LSIRM model with model selection approach for missing at random data.*

Description

lsirm1pl_mar_ss is used to fit 1pl LSIRM model with model selection approach based on spike-and-slab priors in incomplete data assumed to be missing at random. lsirm1pl_mar_ss factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space, while considering the missing element under the assumption of missing at random. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm1pl_mar_ss(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_gamma = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
```

```
  pr_spike_mean = -3,
  pr_spike_sd = 1,
  pr_slab_mean = 0.5,
  pr_slab_sd = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_xi_a = 1,
  pr_xi_b = 1,
  missing = 99
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 1.0.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_spike_mean	Numeric; mean of spike prior for log gamma default value is -3.
pr_spike_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_slab_mean	Numeric; mean of spike prior for log gamma default value is 0.5.
pr_slab_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_xi_a	Numeric; first shape parameter of beta prior for latent variable xi. default value is 1.
pr_xi_b	Numeric; second shape parameter of beta prior for latent variable xi. default value is 1.
missing	Numeric; a number to replace missing values. default value is 99.

Details

`lsirm1pl_mar_ss` models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space, with γ represents the weight of the distance term:

$$logit(P(Y_{j,i} = 1|\theta_j, \beta_i, \gamma, z_j, w_i)) = \theta_j + \beta_i - \gamma||z_j - w_i||$$

Under the assumption of missing at random, the model takes the missing element into consideration in the sampling procedure. For the details of missing at random assumption and data augmentation, see References. `lsirm1pl_mar_ss` model include model selection approach based on spike-and-slab priors for log gamma. For detail of spike-and-slab priors, see References.

Value

`lsirm1pl_mar_ss` returns an object of list containing the following components:

`beta_estimate`	posterior estimation of beta.
`theta_estimate`	posterior estimation of theta.
`sigma_theta_estimate`	posterior estimation of standard deviation of theta.
`gamma_estimate`	posterior estimation of gamma.
`z_estimate`	posterior estimation of z.
`w_estimate`	posterior estimation of w.
`pi_estimate`	posterior estimation of phi. inclusion probability of gamma. if estimation of phi is less than 0.5, choose Rasch model with gamma = 0, otherwise latent space model with gamma > 0.
`imp_estimate`	probability of imputating a missing value with 1.
`beta`	posterior samples of beta.
`theta`	posterior samples of theta.
`theta_sd`	posterior samples of standard deviation of theta.
`gamma`	posterior samples of gamma.
`z`	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
`w`	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
`pi`	posterior samples of phi which is indicator of spike and slab prior. If phi is 1, log gamma follows the slab prior, otherwise follows the spike prior.
`imp`	imputation for missing Values using posterior samples.
`accept_beta`	accept ratio of beta.
`accept_theta`	accept ratio of theta.
`accept_w`	accept ratio of w.
`accept_z`	accept ratio of z.
`accept_gamma`	accept ratio of gamma.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons. Ishwaran, H., & Rao, J. S. (2005). Spike and slab variable selection: frequentist and Bayesian strategies. The Annals of Statistics, 33(2), 730-773.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm1pl_mar_ss(data)

# The code following can achieve the same result.
lsirm_result <- lsirm1pl(data, spikenslab = TRUE, fixed_gamma = FALSE, missing_data = 'mar')
```

`lsirm1pl_mcar` *1pl LSIRM model for missing completely at random data.*

Description

lsirm1pl_mcar is used to fit 1pl LSIRM model in incomplete data assumed to be missing completely at random. lsirm1pl_mcar factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space, while ignoring the missing element under the assumption of missing completely at random. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm1pl_mcar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_gamma = 0.025,
  jump_z = 0.5,
```

```
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_gamma = 0.5,
  pr_sd_gamma = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  missing = 99
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 0.025.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_gamma	Numeric; mean of log normal prior for gamma. default value is 0.5.
pr_sd_gamma	Numeric; standard deviation of log normal prior for gamma. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

`lsirm1pl_mcar` models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space, with γ represents the weight of the distance term:

$$logit(P(Y_{j,i} = 1|\theta_j, \beta_i, \gamma, z_j, w_i)) = \theta_j + \beta_i - \gamma||z_j - w_i||$$

Under the assumption of missing completely at random, the model ignores the missing element in doing inference. For the details of missing completely at random assumption and data augmentation, see References.

Value

`lsirm1pl_mcar` returns an object of list containing the following components:

`beta_estimate`	posterior estimation of beta.
`theta_estimate`	posterior estimation of theta.
`sigma_theta_estimate`	posterior estimation of standard deviation of theta.
`gamma_estimate`	posterior estimation of gamma.
`z_estimate`	posterior estimation of z.
`w_estimate`	posterior estimation of w.
`beta`	posterior samples of beta.
`theta`	posterior samples of theta.
`theta_sd`	posterior samples of standard deviation of theta.
`gamma`	posterior samples of gamma.
`z`	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
`w`	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
`accept_beta`	accept ratio of beta.
`accept_theta`	accept ratio of theta.
`accept_z`	accept ratio of z.
`accept_w`	accept ratio of w.
`accept_gamma`	accept ratio of gamma.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm1pl_mcar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm1pl(data, spikenslab = FALSE, fixed_gamma = FALSE, missing_data = 'mcar')
```

`lsirm1pl_mcar_ss` *1pl LSIRM model with model selection approach for missing completely at random data.*

Description

lsirm1pl_mcar_ss is used to fit LSIRM model with model selection approach based on spike-and-slab priors in incomplete data assumed to be missing completely at random. lsirm1pl_mcar_ss factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space, while ignoring the missing element under the assumption of missing completely at random. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm1pl_mcar_ss(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_gamma = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
```

```
  pr_spike_mean = -3,
  pr_spike_sd = 1,
  pr_slab_mean = 0.5,
  pr_slab_sd = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_xi_a = 1,
  pr_xi_b = 1,
  missing = 99
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 1.0.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_spike_mean	Numeric; mean of spike prior for log gamma default value is -3.
pr_spike_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_slab_mean	Numeric; mean of spike prior for log gamma default value is 0.5.
pr_slab_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_xi_a	Numeric; first shape parameter of beta prior for latent variable xi. default value is 1.
pr_xi_b	Numeric; second shape parameter of beta prior for latent variable xi. default value is 1.
missing	Numeric; a number to replace missing values. default value is 99.

Details

`lsirm1pl_mcar_ss` models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space, with γ represents the weight of the distance term:

$$logit(P(Y_{j,i} = 1|\theta_j, \beta_i, \gamma, z_j, w_i)) = \theta_j + \beta_i - \gamma||z_j - w_i||$$

Under the assumption of missing completely at random, the model ignores the missing element in doing inference. For the details of missing completely at random assumption and data augmentation, see References. `lsirm1pl_mcar_ss` model include model selection approach based on spike-and-slab priors for log gamma. For detail of spike-and-slab priors, see References.

Value

`lsirm1pl_mcar_ss` returns an object of list containing the following components:

`beta_estimate`	posterior estimation of beta.
`theta_estimate`	posterior estimation of theta.
`sigma_theta_estimate`	posterior estimation of standard deviation of theta.
`gamma_estimate`	posterior estimation of gamma.
`z_estimate`	posterior estimation of z.
`w_estimate`	posterior estimation of w.
`pi_estimate`	posterior estimation of phi. inclusion probability of gamma. if estimation of phi is less than 0.5, choose Rasch model with gamma = 0, otherwise latent space model with gamma > 0.
`beta`	posterior samples of beta.
`theta`	posterior samples of theta.
`theta_sd`	posterior samples of standard deviation of theta.
`gamma`	posterior samples of gamma.
`z`	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
`w`	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
`pi`	posterior samples of phi which is indicator of spike and slab prior. If phi is 1, log gamma follows the slab prior, otherwise follows the spike prior.
`accept_beta`	accept ratio of beta.
`accept_theta`	accept ratio of theta.
`accept_w`	accept ratio of w.
`accept_z`	accept ratio of z.
`accept_gamma`	accept ratio of gamma.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons. Ishwaran, H., & Rao, J. S. (2005). Spike and slab variable selection: frequentist and Bayesian strategies. The Annals of Statistics, 33(2), 730-773.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm1pl_mcar_ss(data)

# The code following can achieve the same result.
lsirm_result <- lsirm1pl(data, spikenslab = TRUE, fixed_gamma = FALSE, missing_data = 'mcar')
```

---

lsirm1pl_normal *1pl LSIRM model with normal likelihood*

Description

lsirm1pl_normal integrates all functions related to 1pl LSIRM with normal likelihood using multiplicative effect.

Usage

```
lsirm1pl_normal(
  data,
  spikenslab = FALSE,
  fixed_gamma = FALSE,
  missing_data = NA,
  ...
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
spikenslab	Whether to use a model selection approach.

fixed_gamma	Whether fix gamma to 1.
missing_data	The assumed missing type. One of NA, "mar" and "mcar". Default uses NA.
...	Additional arguments for the corresponding function.

Value

lsirm1pl_normal returns an object of list. See corresponding function.

Note

If both spikenslab and fixed_gamma are set TRUE, it returns error because both are related to gamma.

See Also

lsirm1pl_normal_o, lsirm1pl_normal_fixed_gamma, lsirm1pl_normal_mar, lsirm1pl_normal_mcar, lsirm1pl_normal_fixed_gamma_mar, lsirm1pl_normal_fixed_gamma_mcar, lsirm1pl_normal_ss, lsirm1pl_normal_mar_ss, lsirm1pl_normal_mcar_ss

---

lsirm1pl_normal_fixed_gamma

1pl LSIRM model fixing gamma to 1 with normal likelihood

Description

lsirm1pl_normal_fixed_gamma is used to fit 1pl LSIRM model for continuous variable with gamma fixed to 1. lsirm1pl_normal_fixed_gamma factorizes continuous item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space, while ignoring the missing element under the assumption of missing at random. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm1pl_normal_fixed_gamma(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
```

```
  pr_mean_theta = 0,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001
)
```

Arguments

data	Matrix; continuous item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.

Details

lsirm1pl_normal_fixed_gamma models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space:

$$Y_{j,i} = \theta_j + \beta_i - ||z_j - w_i|| + e_{j,i}$$

where the error $e_{j,i} \sim N(0, \sigma^2)$.

Value

lsirm1pl_normal_fixed_gamma returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
sigma_estimate	posterior estimation of standard deviation.
z_estimate	posterior estimation of z.
w_estimate	posterior estimation of w.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
sigma	posterior samples of standard deviation.
z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.

Examples

```
# generate example (continuous) item response matrix
data     <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm1pl_normal_fixed_gamma(data)

# The code following can achieve the same result.
lsirm_result <- lsirm1pl_normal(data, spikenslab = FALSE, fixed_gamma = TRUE)
```

`lsirm1pl_normal_fixed_gamma_mar` *1pl LSIRM model fixing gamma to 1 with normal likelihood for missing at random data.*

Description

lsirm1pl_normal_fixed_gamma_mar is used to fit 1pl LSIRM model for continuous variable with gamma fixed to 1 in incomplete data assumed to be missing at random.

lsirm1pl_normal_fixed_gamma_mar factorizes continuous item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space, while considering the missing element under the assumption of missing at random. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm1pl_normal_fixed_gamma_mar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001,
  missing = 99
)
```

Arguments

`data`	Matrix; continuous item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
`ndim`	Numeric; dimension of latent space. default value is 2.
`niter`	Numeric; number of iterations to run MCMC sampling. default value is 15000.
`nburn`	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.

nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

lsirm1pl_normal_fixed_gamma_mar models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space:

$$Y_j, i = \theta_j + \beta_i - ||z_j - w_i|| + e_{ji}$$

where the error $e_j i\ N(0, \sigma^2)$ Under the assumption of missing at random, the model takes the missing element into consideration in the sampling procedure. For the details of missing at random assumption and data augmentation, see References.

Value

lsirm1pl_normal_fixed_gamma_mar returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
sigma_estimate	posterior estimation of standard deviation.
z_estimate	posterior estimation of z.
w_estimate	posterior estimation of w.

imp_estimate	estimation of imputing missing values.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
sigma	posterior samples of standard deviation.
z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
imp	imputation for missing Values using posterior samples.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.

Examples

```
# generate example (continuous) item response matrix
data     <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm1pl_normal_fixed_gamma_mar(data)

# The code following can achieve the same result.
 lsirm_result <- lsirm1pl_normal(data, spikenslab = FALSE, fixed_gamma = TRUE,
                                 missing_data = 'mar')
```

---

lsirm1pl_normal_fixed_gamma_mcar

1pl LSIRM model fixing gamma to 1 with normal likelihood for missing completely at random data.

Description

lsirm1pl_normal_fixed_gamma_mcar is used to fit 1pl LSIRM model for continuous variable with gamma fixed to 1 in incomplete data assumed to be missing completely at random.

lsirm1pl_normal_fixed_gamma_mcar factorizes continuous item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space, while ignoring the missing element under the assumption of missing completely at random. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm1pl_normal_fixed_gamma_mcar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001,
  missing = 99
)
```

Arguments

data	Matrix; continuous item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.

pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

lsirm1pl_normal_fixed_gamma_mcar models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space:

$$Y_{j,i} = \theta_j + \beta_i - ||z_j - w_i|| + e_{j,i}$$

where the error $e_{j,i} \sim N(0, \sigma^2)$ Under the assumption of missing completely at random, the model ignores the missing element in doing inference. For the details of missing completely at random assumption and data augmentation, see References.

Value

lsirm1pl_normal_fixed_gamma_mcar returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
sigma_estimate	posterior estimation of standard deviation.
z_estimate	posterior estimation of z.
w_estimate	posterior estimation of w.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
sigma	posterior samples of standard deviation.
z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.

Examples

```
# generate example (continuous) item response matrix
data     <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm1pl_normal_fixed_gamma_mcar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm1pl_normal(data, spikenslab = FALSE, fixed_gamma = TRUE,
                                missing_data = 'mcar')
```

`lsirm1pl_normal_mar` *1pl LSIRM model with normal likelihood for missing at random data.*

Description

lsirm1pl_normal_mar is used to fit LSIRM model for continuous variable with 1pl in incomplete data assumed to be missing at random. lsirm1pl_normal_mar factorizes continuous item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space, while considering the missing element under the assumption of missing at random. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm1pl_normal_mar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_gamma = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_gamma = 0.5,
```

```
  pr_sd_gamma = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001,
  missing = 99
)
```

Arguments

data	Matrix; continuous item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 0.025.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_gamma	Numeric; mean of log normal prior for gamma. default value is 0.5.
pr_sd_gamma	Numeric; standard deviation of log normal prior for gamma. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

`lsirm1pl_normal_mar` models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space, with γ represents the weight of the distance term:

$$Y_j, i = \theta_j + \beta_i - \gamma||z_j - w_i|| + e_{ji}$$

where the error $e_{ji} \sim N(0, \sigma^2)$ Under the assumption of missing at random, the model takes the missing element into consideration in the sampling procedure. For the details of missing at random assumption and data augmentation, see References.

Value

`lsirm1pl_normal_mar` returns an object of list containing the following components:

`beta_estimate`	posterior estimation of beta.
`theta_estimate`	posterior estimation of theta.
`sigma_theta_estimate`	posterior estimation of standard deviation of theta.
`sigma_estimate`	posterior estimation of standard deviation.
`gamma_estimate`	posterior estimation of gamma.
`z_estimate`	posterior estimation of z.
`w_estimate`	posterior estimation of w.
`imp_estimate`	estimation of imputing missing values.
`beta`	posterior samples of beta.
`theta`	posterior samples of theta.
`theta_sd`	posterior samples of standard deviation of theta.
`sigma`	posterior samples of standard deviation.
`gamma`	posterior samples of gamma.
`z`	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
`w`	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
`imp`	imputation for missing Values using posterior samples.
`accept_beta`	accept ratio of beta.
`accept_theta`	accept ratio of theta.
`accept_w`	accept ratio of w.
`accept_z`	accept ratio of z.
`accept_gamma`	accept ratio of gamma.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons.

Examples

```
# generate example (continuous) item response matrix
data     <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm1pl_normal_mar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm1pl_normal(data, spikenslab = FALSE, fixed_gamma = FALSE,
                                missing_data = 'mar')
```

---

lsirm1pl_normal_mar_ss

1pl LSIRM model with normal likelihood and model selection approach for missing at random data.

Description

lsirm1pl_normal_mar_ss is used to fit LSIRM model with model selection approach based on spike-and-slab priors for continuous variable with 1pl in incomplete data assumed to be missing at random. lsirm1pl_normal_mar_ss factorizes continuous item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space, while considering the missing element under the assumption of missing at random. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm1pl_normal_mar_ss(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_gamma = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
```

```
  pr_mean_theta = 0,
  pr_spike_mean = -3,
  pr_spike_sd = 1,
  pr_slab_mean = 0.5,
  pr_slab_sd = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001,
  pr_xi_a = 0.001,
  pr_xi_b = 0.001,
  missing = 99
)
```

Arguments

data	Matrix; continuous item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 0.025.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_spike_mean	Numeric; mean of spike prior for log gamma default value is -3.
pr_spike_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_slab_mean	Numeric; mean of spike prior for log gamma default value is 0.5.
pr_slab_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.

pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.
pr_xi_a	Numeric; first shape parameter of beta prior for latent variable xi. default value is 1.
pr_xi_b	Numeric; second shape parameter of beta prior for latent variable xi. default value is 1.
missing	Numeric; a number to replace missing values. default value is 99.

Details

lsirm1pl_normal_mar_ss models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space, with γ represents the weight of the distance term:

$$Y_{j,i} = \theta_j + \beta_i - \gamma||z_j - w_i|| + e_{j,i}$$

where the error $e_{j,i} \sim N(0, \sigma^2)$ Under the assumption of missing at random, the model takes the missing element into consideration in the sampling procedure. For the details of missing at random assumption and data augmentation, see References. lsirm1pl_normal_mar_ss model include model selection approach based on spike-and-slab priors for log gamma. For detail of spike-and-slab priors, see References.

Value

lsirm1pl_normal_mar_ss returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
sigma_estimate	posterior estimation of standard deviation.
gamma_estimate	posterior estimation of gamma.
z_estimate	posterior estimation of z.
w_estimate	posterior estimation of w.
pi_estimate	posterior estimation of phi. inclusion probability of gamma. if estimation of phi is less than 0.5, choose Rasch model with gamma = 0, otherwise latent space model with gamma > 0.
imp_estimate	estimation of imputing missing values.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
sigma	posterior samples of standard deviation.
gamma	posterior samples of gamma.

z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
pi	posterior samples of phi which is indicator of spike and slab prior. If phi is 1, log gamma follows the slab prior, otherwise follows the spike prior.
imp	imputation for missing Values using posterior samples.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.
accept_gamma	accept ratio of gamma.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons. Ishwaran, H., & Rao, J. S. (2005). Spike and slab variable selection: frequentist and Bayesian strategies. The Annals of Statistics, 33(2), 730-773.

Examples

```
# generate example (continuous) item response matrix
data     <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm1pl_normal_mar_ss(data)

# The code following can achieve the same result.
lsirm_result <- lsirm1pl_normal(data, spikenslab = TRUE, fixed_gamma = FALSE,
                                missing_data = 'mar')
```

---

lsirm1pl_normal_mcar *1pl LSIRM model with normal likelihood for missing completely at random data.*

Description

lsirm1pl_normal_mcar is used to fit LSIRM model with 1pl in incomplete data assumed to be missing completely at random. lsirm1pl_normal_mcar factorizes continuous item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space, while ignoring the missing element under the assumption of missing completely at random. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm1pl_normal_mcar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_gamma = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_gamma = 0.5,
  pr_sd_gamma = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001,
  missing = 99
)
```

Arguments

data	Matrix; continuous item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 0.025.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.

pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_gamma	Numeric; mean of log normal prior for gamma. default value is 0.5.
pr_sd_gamma	Numeric; standard deviation of log normal prior for gamma. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

lsirm1pl_normal_mcar models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space, with γ represents the weight of the distance term:

$$Y_{j,i} = \theta_j + \beta_i - \gamma||z_j - w_i|| + e_{j,i}$$

where the error $e_{j,i} \sim N(0, \sigma^2)$ Under the assumption of missing completely at random, the model ignores the missing element in doing inference. For the details of missing at random assumption and data augmentation, see References.

Value

lsirm1pl_normal_mcar returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
sigma_estimate	posterior estimation of standard deviation.
gamma_estimate	posterior estimation of gamma.
z_estimate	posterior estimation of z.
w_estimate	posterior estimation of w.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
sigma	posterior samples of standard deviation.
gamma	posterior samples of gamma.

z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.
accept_gamma	accept ratio of gamma.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons.

Examples

```
# generate example (continuous) item response matrix
data     <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm1pl_normal_mcar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm1pl_normal(data, spikenslab = FALSE, fixed_gamma = FALSE,
                                missing_data = 'mcar')
```

---

lsirm1pl_normal_mcar_ss

1pl LSIRM model with normal likelihood and model selection approach for missing completely at random data.

Description

lsirm1pl_normal_mcar_ss is used to fit LSIRM model with model selection approach based on spike-and-slab priors for continuous variable with 1pl in incomplete data assumed to be missing completely at random. lsirm1pl_normal_mcar_ss factorizes continuous item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space, while ignoring the missing element under the assumption of missing completely at random. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm1pl_normal_mcar_ss(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_gamma = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_spike_mean = -3,
  pr_spike_sd = 1,
  pr_slab_mean = 0.5,
  pr_slab_sd = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001,
  pr_xi_a = 0.001,
  pr_xi_b = 0.001,
  missing = 99
)
```

Arguments

data	Matrix; continuous item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 0.025.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.

jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_spike_mean	Numeric; mean of spike prior for log gamma default value is -3.
pr_spike_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_slab_mean	Numeric; mean of spike prior for log gamma default value is 0.5.
pr_slab_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.
pr_xi_a	Numeric; first shape parameter of beta prior for latent variable xi. default value is 1.
pr_xi_b	Numeric; second shape parameter of beta prior for latent variable xi. default value is 1.
missing	Numeric; a number to replace missing values. default value is 99.

Details

lsirm1pl_normal_mcar_ss models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space, with γ represents the weight of the distance term:

$$Y_{j,i} = \theta_j + \beta_i - \gamma||z_j - w_i|| + e_{j,i}$$

where the error $e_{j,i} \sim N(0, \sigma^2)$. Under the assumption of missing completely at random, the model ignores the missing element in doing inference. For the details of missing at random assumption and data augmentation, see References. lsirm1pl_normal_mcar_ss model include model selection approach based on spike-and-slab priors for log gamma. For detail of spike-and-slab priors, see References.

Value

lsirm1pl_normal_mcar_ss returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
sigma_estimate	posterior estimation of standard deviation.

gamma_estimate	posterior estimation of gamma.
z_estimate	posterior estimation of z.
w_estimate	posterior estimation of w.
pi_estimate	posterior estimation of phi. inclusion probability of gamma. if estimation of phi is less than 0.5, choose Rasch model with gamma = 0, otherwise latent space model with gamma > 0.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
sigma	posterior samples of standard deviation.
gamma	posterior samples of gamma.
z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
pi	posterior samples of phi which is indicator of spike and slab prior. If phi is 1, log gamma follows the slab prior, otherwise follows the spike prior.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.
accept_gamma	accept ratio of gamma.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons. Ishwaran, H., & Rao, J. S. (2005). Spike and slab variable selection: frequentist and Bayesian strategies. The Annals of Statistics, 33(2), 730-773.

Examples

```
# generate example (continuous) item response matrix
data     <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm1pl_normal_mcar_ss(data)

# The code following can achieve the same result.
lsirm_result <- lsirm1pl_normal(data, spikenslab = TRUE, fixed_gamma = FALSE,
                                missing_data = 'mcar')
```

`lsirm1pl_normal_o` *1pl LSIRM model with normal likelihood.*

Description

lsirm1pl_normal_o is used to fit LSIRM model for continuous variable with 1pl. lsirm1pl_normal_o factorizes continuous item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm1pl_normal_o(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_gamma = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_gamma = 0.5,
  pr_sd_gamma = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001
)
```

Arguments

`data`	Matrix; continuous item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
`ndim`	Numeric; dimension of latent space. default value is 2.
`niter`	Numeric; number of iterations to run MCMC sampling. default value is 15000.
`nburn`	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
`nthin`	Numeric;number of thinning, MCMC iterations to discard. default value is 5.

nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 0.025.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_gamma	Numeric; mean of log normal prior for gamma. default value is 0.5.
pr_sd_gamma	Numeric; standard deviation of log normal prior for gamma. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.

Details

lsirm1pl_normal_o models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space, with γ represents the weight of the distance term:

$$Y_{j,i} = \theta_j + \beta_i - \gamma||z_j - w_i|| + e_{j,i}$$

where the error $e_{j,i} \sim N(0, \sigma^2)$.

Value

lsirm1pl_normal_o returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
sigma_estimate	posterior estimation of standard deviation.
gamma_estimate	posterior estimation of gamma.
z_estimate	posterior estimation of z.

w_estimate	posterior estimation of w.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
sigma	posterior samples of standard deviation.
gamma	posterior samples of gamma.
z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.
accept_gamma	accept ratio of gamma.

Examples

```
# generate example (continuous) item response matrix
data     <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)

lsirm_result <- lsirm1pl_normal_o(data)

# The code following can achieve the same result.
lsirm_result <- lsirm1pl_normal(data, spikenslab = FALSE, fixed_gamma = FALSE)
```

---

lsirm1pl_normal_ss *1pl LSIRM model with normal likelihood and model selection approach.*

Description

lsirm1pl_normal_ss is used to fit LSIRM model with model selection approach based on spike-and-slab priors for continuous variable with 1pl. LSIRM factorizes continuous item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm1pl_normal_ss(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_gamma = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_spike_mean = -3,
  pr_spike_sd = 1,
  pr_slab_mean = 0.5,
  pr_slab_sd = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001,
  pr_xi_a = 0.001,
  pr_xi_b = 0.001
)
```

Arguments

data	Matrix; continuous item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 0.025.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.

jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_spike_mean	Numeric; mean of spike prior for log gamma default value is -3.
pr_spike_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_slab_mean	Numeric; mean of spike prior for log gamma default value is 0.5.
pr_slab_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.
pr_xi_a	Numeric; first shape parameter of beta prior for latent variable xi. default value is 1.
pr_xi_b	Numeric; second shape parameter of beta prior for latent variable xi. default value is 1.

Details

`lsirm1pl_normal_ss` models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space, with γ represents the weight of the distance term:

$$Y_{j,i} = \theta_j + \beta_i - \gamma||z_j - w_i|| + e_{j,i}$$

where the error $e_{j,i} \sim N(0, \sigma^2)$. `lsrm1pl_noraml_ss` model include model selection approach based on spike-and-slab priors for log gamma. For detail of spike-and-slab priors, see References.

Value

`lsirm1pl_normal_ss` returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
sigma_estimate	posterior estimation of standard deviation.
gamma_estimate	posterior estimation of gamma.
z_estimate	posterior estimation of z.
w_estimate	posterior estimation of w.

pi_estimate	posterior estimation of phi. inclusion probability of gamma. if estimation of phi is less than 0.5, choose Rasch model with gamma = 0, otherwise latent space model with gamma > 0.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
sigma	posterior samples of standard deviation.
gamma	posterior samples of gamma.
z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
pi	posterior samples of phi which is indicator of spike and slab prior. If phi is 1, log gamma follows the slab prior, otherwise follows the spike prior.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.
accept_gamma	accept ratio of gamma.

References

Ishwaran, H., & Rao, J. S. (2005). Spike and slab variable selection: Frequentist and Bayesian strategies (Vol. 33). The Annals of Statistics

Examples

```
# generate example (continuous) item response matrix
data     <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)

lsirm_result <- lsirm1pl_normal_ss(data)

# The code following can achieve the same result.
 lsirm_result <- lsirm1pl_normal(data, spikenslab = TRUE, fixed_gamma = FALSE)
```

---

lsirm1pl_o *1pl LSIRM model.*

Description

lsirm1pl_o is used to fit 1pl LSIRM model. lsirm1pl_o factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm1pl_o(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_gamma = 0.025,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_gamma = 0.5,
  pr_sd_gamma = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 0.025.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_gamma	Numeric; mean of log normal prior for gamma. default value is 0.5.

pr_sd_gamma	Numeric; standard deviation of log normal prior for gamma. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.

Details

lsirm1pl_o models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space, with γ represents the weight of the distance term:

$$logit(P(Y_{j,i} = 1|\theta_j, \beta_i, \gamma, z_j, w_i)) = \theta_j + \beta_i - \gamma||z_j - w_i||$$

Value

lsirm1pl_o returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
gamma_estimate	posterior estimation of gamma.
z_estimate	posterior estimation of z.
w_estimate	posterior estimation of w.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
gamma	posterior samples of gamma.
z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_z	accept ratio of z.
accept_w	accept ratio of w.
accept_gamma	accept ratio of gamma.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5),ncol=10,nrow=50)

lsirm_result <- lsirm1pl_o(data)

# The code following can achieve the same result.
lsirm_result <- lsirm1pl(data, spikenslab = FALSE, fixed_gamma = FALSE)
```

`lsirm1pl_ss` *1pl LSIRM model with model selection approach.*

Description

lsirm1pl_ss is used to fit LSIRM model with model selection approach based on spike-and-slab priors. LSIRM factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm1pl_ss(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_gamma = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_spike_mean = -3,
  pr_spike_sd = 1,
  pr_slab_mean = 0.5,
  pr_slab_sd = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_xi_a = 1,
  pr_xi_b = 1
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 1.0.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_spike_mean	Numeric; mean of spike prior for log gamma default value is -3.
pr_spike_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_slab_mean	Numeric; mean of spike prior for log gamma default value is 0.5.
pr_slab_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_xi_a	Numeric; first shape parameter of beta prior for latent variable xi. default value is 1.
pr_xi_b	Numeric; second shape parameter of beta prior for latent variable xi. default value is 1.

Details

lsirm1pl_ss models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space, with γ represents the weight of the distance term:

$$logit(P(Y_{j,i} = 1|\theta_j, \beta_i, \gamma, z_j, w_i)) = \theta_j + \beta_i - \gamma||z_j - w_i||$$

lsirm1pl_ss model include model selection approach based on spike-and-slab priors for log gamma. For detail of spike-and-slab priors, see References.

Value

lsirm1pl_ss returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
gamma_estimate	posterior estimation of gamma.
z_estimate	posterior estimation of z.
w_estimate	posterior estimation of w.
pi_estimate	posterior estimation of phi. inclusion probability of gamma. if estimation of phi is less than 0.5, choose Rasch model with gamma = 0, otherwise latent space model with gamma > 0.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
gamma	posterior samples of gamma.
z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
pi	posterior samples of phi which is indicator of spike and slab prior. If phi is 1, log gamma follows the slab prior, otherwise follows the spike prior.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.
accept_gamma	accept ratio of gamma.

References

Ishwaran, H., & Rao, J. S. (2005). Spike and slab variable selection: Frequentist and Bayesian strategies (Vol. 33). The Annals of Statistics

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5),ncol=10,nrow=50)

lsirm_result <- lsirm1pl_ss(data)

# The code following can achieve the same result.
lsirm_result <- lsirm1pl(data, spikenslab = TRUE, fixed_gamma = FALSE)
```

lsirm2pl *2pl LSIRM model*

Description

lsirm2pl integrates all functions related to 2pl LSIRM

Usage

```
lsirm2pl(data, spikenslab = FALSE, fixed_gamma = FALSE, missing_data = NA, ...)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
spikenslab	Whether to use a model selection approach.
fixed_gamma	Whether fix gamma to 1.
missing_data	The assumed missing type. One of NA, "mar" and "mcar". Default uses NA.
...	Additional arguments for the corresponding function.

Value

lsirm2pl returns an object of list. See corresponding function.

Note

If both spikenslab and fixed_gamma are set TRUE, it returns error because both are related to gamma.

See Also

lsirm2pl_o, lsirm2pl_fixed_gamma, lsirm2pl_mar, lsirm2pl_mcar,lsirm2pl_fixed_gamma_mar, lsirm2pl_fixed_gamma_mcar, lsirm2pl_ss, lsirm2pl_mar_ss, lsirm2pl_mcar_ss

`lsirm2pl_fixed_gamma` *2pl LSIRM model fixing gamma to 1.*

Description

lsirm2pl_fixed_gamma is used to fit 2pl LSIRM model fixing gamma to 1. lsirm2pl_fixed_gamma factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm2pl_fixed_gamma(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001
)
```

Arguments

`data`	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
`ndim`	Numeric; dimension of latent space. default value is 2.
`niter`	Numeric; number of iterations to run MCMC sampling. default value is 15000.
`nburn`	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
`nthin`	Numeric;number of thinning, MCMC iterations to discard. default value is 5.

nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha. default value is 1.0.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; mean of normal prior for beta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.

Details

lsirm2pl_fixed_gamma models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$logit(P(Y_{j,i} = 1|\theta_j, \alpha_i, \beta_i, z_j, w_i)) = \theta_j * \alpha_i + \beta_i - ||z_j - w_i||$$

Value

lsirm2pl_fixed_gamma returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
alpha_estimate	posterior estimation of alpha.
z_estimate	posterior estimation of z.
w_estimate	posterior estimation of w.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
alpha	posterior samples of alpha.
z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.

w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.
accept_alpha	accept ratio of alpha.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5),ncol=10,nrow=50)

lsirm_result <- lsirm2pl_fixed_gamma(data)

# The code following can achieve the same result.
lsirm_result <- lsirm2pl(data, spikenslab = FALSE, fixed_gamma = TRUE)
```

---

lsirm2pl_fixed_gamma_mar

2pl LSIRM model fixing gamma to 1 for missing at random data.

Description

lsirm2pl_fixed_gamma_mar is used to fit 2pl LSIRM model fixing gamma to 1 in incomplete data assumed to be missing at random. lsirm2pl_fixed_gamma_mar factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space, while considering the missing element under the assumption of missing at random. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm2pl_fixed_gamma_mar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
```

```
  jump_alpha = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  missing = 99
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha. default value is 1.0.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; mean of normal prior for beta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

`lsirm2pl_fixed_gamma_mar` models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$logit(P(Y_{j,i} = 1|\theta_j, \alpha_i, \beta_i, z_j, w_i)) = \theta_j * \alpha_i + \beta_i - ||z_j - w_i||$$

Under the assumption of missing at random, the model takes the missing element into consideration in the sampling procedure. For the details of missing at random assumption and data augmentation, see References.

Value

`lsirm2pl_fixed_gamma_mar` returns an object of list containing the following components:

`beta_estimate`	posterior estimation of beta.
`theta_estimate`	posterior estimation of theta.
`sigma_theta_estimate`	posterior estimation of standard deviation of theta.
`alpha_estimate`	posterior estimation of alpha.
`z_estimate`	posterior estimation of z.
`w_estimate`	posterior estimation of w.
`imp_estimate`	probability of imputating a missing value with 1.
`beta`	posterior samples of beta.
`theta`	posterior samples of theta.
`theta_sd`	posterior samples of standard deviation of theta.
`alpha`	posterior samples of alpha.
`z`	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
`w`	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
`imp`	imputation for missing Values using posterior samples.
`accept_beta`	accept ratio of beta.
`accept_theta`	accept ratio of theta.
`accept_w`	accept ratio of w.
`accept_z`	accept ratio of z.
`accept_alpha`	accept ratio of alpha.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm2pl_fixed_gamma_mar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm2pl(data, spikenslab = FALSE, fixed_gamma = TRUE, missing_data = "mar")
```

---

lsirm2pl_fixed_gamma_mcar

2pl LSIRM model fixing gamma to 1 for missing completely at random data.

Description

lsirm2pl_fixed_gamma_mcar is used to fit 2pl LSIRM model fixing gamma to 1 in incomplete data assumed to be missing completely at random. lsirm2pl_fixed_gamma_mcar factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space, while ignoring the missing element under the assumption of missing completely at random. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm2pl_fixed_gamma_mcar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
```

```
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  missing = 99
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha. default value is 1.0.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; mean of normal prior for beta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

lsirm2pl_fixed_gamma_mcar models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$logit(P(Y_{j,i} = 1|\theta_j, \alpha_i, \beta_i, z_j, w_i)) = \theta_j * \alpha_i + \beta_i - ||z_j - w_i||$$

Under the assumption of missing completely at random, the model ignores the missing element in doing inference. For the details of missing completely at random assumption and data augmentation, see References.

Value

`lsirm2pl_fixed_gamma_mar` returns an object of list containing the following components:

`beta_estimate`	posterior estimation of beta.
`theta_estimate`	posterior estimation of theta.
`sigma_theta_estimate`	posterior estimation of standard deviation of theta.
`alpha_estimate`	posterior estimation of alpha.
`z_estimate`	posterior estimation of z.
`w_estimate`	posterior estimation of w.
`beta`	posterior samples of beta.
`theta`	posterior samples of theta.
`theta_sd`	posterior samples of standard deviation of theta.
`alpha`	posterior samples of alpha.
`z`	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
`w`	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
`accept_beta`	accept ratio of beta.
`accept_theta`	accept ratio of theta.
`accept_w`	accept ratio of w.
`accept_z`	accept ratio of z.
`accept_alpha`	accept ratio of alpha.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99
```

```
lsirm_result <- lsirm2pl_fixed_gamma_mcar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm2pl(data, spikenslab = FALSE, fixed_gamma = TRUE, missing_data = "mcar")
```

`lsirm2pl_mar` *2pl LSIRM model for missing at random data.*

Description

lsirm2pl_mar is used to fit 2pl LSIRM model in incomplete data assumed to be missing at random. lsirm2pl_mar factorizes item response matrix into column-wise item effect, row-wise respondent effect in a latent space, while considering the missing element under the assumption of missing at random. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm2pl_mar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_gamma = 0.025,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_gamma = 0.5,
  pr_sd_gamma = 1,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  missing = 99
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha. default value is 1.0.
jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 0.025.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_gamma	Numeric; mean of log normal prior for gamma. default value is 0.5.
pr_sd_gamma	Numeric; standard deviation of log normal prior for gamma. default value is 1.0.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; mean of normal prior for beta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

lsirm2pl_mar models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j in the shared metric space, with γ represents the weight of the distance term. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$logit(P(Y_{j,i} = 1|\theta_j, \alpha_i, \beta_i, \gamma, z_j, w_i)) = \theta_j * \alpha_i + \beta_i - \gamma||z_j - w_i||$$

Under the assumption of missing at random, the model takes the missing element into consideration in the sampling procedure. For the details of missing at random assumption and data augmentation, see References.

Value

lsirm2pl_mar returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
gamma_estimate	posterior estimation of gamma.
alpha_estimate	posterior estimation of alpha.
z_estimate	posterior estimation of z.
w_estimate	posterior estimation of w.
imp_estimate	
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
gamma	posterior samples of gamma.
alpha	posterior samples of alpha.
z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
imp	
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.
accept_gamma	accept ratio of gamma.
accept_alpha	accept ratio of alpha.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5), ncol=10, nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2), ncol=10, nrow=50)
```

```
# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm2pl_mar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm2pl(data, spikenslab = FALSE, fixed_gamma = FALSE, missing_data = "mar")
```

`lsirm2pl_mar_ss` *2pl LSIRM model with model selection approach for missing at random data.*

Description

lsirm2pl_mar_ss is used to fit 2pl LSIRM model based on spike-and-slab priors in incomplete data assumed to be missing at random. lsirm2pl_mar_ss factorizes item response matrix into column-wise item effect, row-wise respondent effect in a latent space, while considering the missing element under the assumption of missing at random. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm2pl_mar_ss(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_gamma = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_spike_mean = -3,
  pr_spike_sd = 1,
  pr_slab_mean = 0.5,
  pr_slab_sd = 1,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
```

```
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_xi_a = 1,
  pr_xi_b = 1,
  missing = 99
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha. default value is 1.0.
jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 0.025.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_spike_mean	Numeric; mean of spike prior for log gamma default value is -3.
pr_spike_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_slab_mean	Numeric; mean of spike prior for log gamma default value is 0.5.
pr_slab_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; mean of normal prior for beta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_xi_a	Numeric; first shape parameter of beta prior for latent variable xi. default value is 1.
pr_xi_b	Numeric; second shape parameter of beta prior for latent variable xi. default value is 1.
missing	Numeric; a number to replace missing values. default value is 99.

Details

`lsirm2pl_mar_ss` models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j in the shared metric space, with γ represents the weight of the distance term. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$logit(P(Y_{j,i} = 1|\theta_j, \alpha_i, \beta_i, \gamma, z_j, w_i)) = \theta_j * \alpha_i + \beta_i - \gamma||z_j - w_i||$$

Under the assumption of missing at random, the model takes the missing element into consideration in the sampling procedure. For the details of missing at random assumption and data augmentation, see References. `lsirm2pl_mar_ss` model include model selection approach based on spike-and-slab priors for log gamma. For detail of spike-and-slab priors, see References.

Value

`lsirm2pl_mar_ss` returns an object of list containing the following components:

`beta_estimate`	posterior estimation of beta.
`theta_estimate`	posterior estimation of theta.
`sigma_theta_estimate`	posterior estimation of standard deviation of theta.
`gamma_estimate`	posterior estimation of gamma.
`alpha_estimate`	posterior estimation of alpha.
`z_estimate`	posterior estimation of z.
`w_estimate`	posterior estimation of w.
`imp_estimate`	
`pi_estimate`	posterior estimation of phi. inclusion probability of gamma. if estimation of phi is less than 0.5, choose Rasch model with gamma = 0, otherwise latent space model with gamma > 0.
`beta`	posterior samples of beta.
`theta`	posterior samples of theta.
`theta_sd`	posterior samples of standard deviation of theta.
`gamma`	posterior samples of gamma.
`alpha`	posterior samples of alpha.
`z`	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
`w`	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
`imp`	
`pi`	posterior samples of phi which is indicator of spike and slab prior. If phi is 1, log gamma follows the slab prior, otherwise follows the spike prior.
`accept_beta`	accept ratio of beta.
`accept_theta`	accept ratio of theta.

accept_w	accept ratio of w.
accept_z	accept ratio of z.
accept_gamma	accept ratio of gamma.
accept_alpha	accept ratio of alpha.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons. Ishwaran, H., & Rao, J. S. (2005). Spike and slab variable selection: frequentist and Bayesian strategies. The Annals of Statistics, 33(2), 730-773.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5), ncol=10, nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2), ncol=10, nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm2pl_mar_ss(data)

# The code following can achieve the same result.
lsirm_result <- lsirm2pl(data, spikenslab = TRUE, fixed_gamma = FALSE, missing_data = "mar")
```

---

lsirm2pl_mcar *2pl LSIRM model for missing completely at random data.*

Description

lsirm2pl_mcar is used to fit 2pl LSIRM model in incomplete data assumed to be missing completely at random. lsirm2pl_mcar factorizes item response matrix into column-wise item effect, row-wise respondent effect in a latent space, while ignoring the missing element under the assumption of missing completely at random. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm2pl_mcar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_gamma = 0.025,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_gamma = 0.5,
  pr_sd_gamma = 1,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  missing = 99
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha. default value is 1.0.
jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 0.025.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.

pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_gamma	Numeric; mean of log normal prior for gamma. default value is 0.5.
pr_sd_gamma	Numeric; standard deviation of log normal prior for gamma. default value is 1.0.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; mean of normal prior for beta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

lsirm2pl_mcar models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j in the shared metric space, with γ represents the weight of the distance term. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$logit(P(Y_{j,i} = 1|\theta_j, \alpha_i, \beta_i, \gamma, z_j, w_i)) = \theta_j * \alpha_i + \beta_i - \gamma||z_j - w_i||$$

Under the assumption of missing completely at random, the model ignores the missing element in doing inference. For the details of missing completely at random assumption and data augmentation, see References.

Value

lsirm2pl_mar returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
gamma_estimate	posterior estimation of gamma.
alpha_estimate	posterior estimation of alpha.
z_estimate	posterior estimation of z.
w_estimate	posterior estimation of w.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
gamma	posterior samples of gamma.
alpha	posterior samples of alpha.

z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.
accept_gamma	accept ratio of gamma.
accept_alpha	accept ratio of alpha.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5), ncol=10, nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2), ncol=10, nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm2pl_mcar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm2pl(data, spikenslab = FALSE, fixed_gamma = FALSE, missing_data = "mcar")
```

---

lsirm2pl_mcar_ss *2pl LSIRM model with model selection approach for missing completely at random data.*

Description

lsirm2pl_mar_ss is used to fit 2pl LSIRM model based on spike-and-slab priors in incomplete data assumed to be missing completely at random. lsirm2pl_mar_ss factorizes item response matrix into column-wise item effect, row-wise respondent effect in a latent space, while ignoring the missing element under the assumption of missing completely at random. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm2pl_mcar_ss(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_gamma = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_spike_mean = -3,
  pr_spike_sd = 1,
  pr_slab_mean = 0.5,
  pr_slab_sd = 1,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_xi_a = 1,
  pr_xi_b = 1,
  missing = 99
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha. default value is 1.0.

jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 0.025.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_spike_mean	Numeric; mean of spike prior for log gamma default value is -3.
pr_spike_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_slab_mean	Numeric; mean of spike prior for log gamma default value is 0.5.
pr_slab_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; mean of normal prior for beta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_xi_a	Numeric; first shape parameter of beta prior for latent variable xi. default value is 1.
pr_xi_b	Numeric; second shape parameter of beta prior for latent variable xi. default value is 1.
missing	Numeric; a number to replace missing values. default value is 99.

Details

lsirm2pl_mcar_ss models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j in the shared metric space, with γ represents the weight of the distance term. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$logit(P(Y_{j,i} = 1|\theta_j, \alpha_i, \beta_i, \gamma, z_j, w_i)) = \theta_j * \alpha_i + \beta_i - \gamma||z_j - w_i||$$

Under the assumption of missing at random, the model takes the missing element into consideration in the sampling procedure. For the details of missing at random assumption and data augmentation, see References. lsirm2pl_mcar_ss model include model selection approach based on spike-and-slab priors for log gamma. For detail of spike-and-slab priors, see References.

Value

lsirm2pl_mar_ss returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.

gamma_estimate	posterior estimation of gamma.
alpha_estimate	posterior estimation of alpha.
z_estimate	posterior estimation of z.
w_estimate	posterior estimation of w.
pi_estimate	posterior estimation of phi. inclusion probability of gamma. if estimation of phi is less than 0.5, choose Rasch model with gamma = 0, otherwise latent space model with gamma > 0.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
gamma	posterior samples of gamma.
alpha	posterior samples of alpha.
z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
pi	posterior samples of phi which is indicator of spike and slab prior. If phi is 1, log gamma follows the slab prior, otherwise follows the spike prior.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.
accept_gamma	accept ratio of gamma.
accept_alpha	accept ratio of alpha.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons. Ishwaran, H., & Rao, J. S. (2005). Spike and slab variable selection: frequentist and Bayesian strategies. The Annals of Statistics, 33(2), 730-773.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5), ncol=10, nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2), ncol=10, nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm2pl_mcar_ss(data)
```

```
# The code following can achieve the same result.
lsirm_result <- lsirm2pl(data, spikenslab = TRUE, fixed_gamma = FALSE, missing_data = "mcar")
```

`lsirm2pl_normal` *2pl LSIRM model with normal likelihood*

Description

lsirm2pl_normal integrates all functions related to 2pl LSIRM with normal likelihood.

Usage

```
lsirm2pl_normal(
  data,
  spikenslab = FALSE,
  fixed_gamma = FALSE,
  missing_data = NA,
  ...
)
```

Arguments

`data`	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
`spikenslab`	Whether to use a model selection approach.
`fixed_gamma`	Whether fix gamma to 1.
`missing_data`	The assumed missing type. One of NA, "mar" and "mcar". Default uses NA.
`...`	Additional arguments for the corresponding function.

Value

`lsirm2pl_normal` returns an object of list. See corresponding function.

Note

If both `spikenslab` and `fixed_gamma` are set `TRUE`, it returns error because both are related to `gamma`.

See Also

`lsirm2pl_normal_o`, `lsirm2pl_normal_fixed_gamma`, `lsirm2pl_normal_mar`, `lsirm2pl_normal_mcar`,`lsirm2pl_normal_fixed_gamma_mar`, `lsirm2pl_normal_fixed_gamma_mcar`, `lsirm2pl_normal_ss`, `lsirm2pl_normal_mar_ss`, `lsirm2pl_normal_mcar_ss`

lsirm2pl_normal_fixed_gamma *2pl LSIRM model fixing gamma to 1 with normal likelihood*

Description

lsirm2pl_normal_fixed_gamma is used to fit 2pl LSIRM model with gamma fixed to 1 for continuous variable. lsirm2pl_normal_fixed_gamma factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm2pl_normal_fixed_gamma(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001
)
```

Arguments

data	Matrix; continuous item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.

nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha default value is 1.0.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; mean of normal prior for beta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.

Details

lsirm2pl_normal_fixed_gamma models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$Y_{j,i} = \theta_j + \beta_i - \gamma||z_j - w_i|| + e_{j,i}$$

where the error $e_{j,i} \sim N(0, \sigma^2)$

Value

lsirm2pl_normal_fixed_gamma returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
sigma_estimate	posterior estimation of standard deviation.

alpha_estimate	posterior estimation of alpha.
z_estimate	posterior estimation of z.
w_estimate	posterior estimation of w.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
sigma	posterior samples of standard deviation.
alpha	posterior samples of alpha.
z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.
accept_alpha	accept ratio of alpha.

Examples

```
# generate example (continuous) item response matrix
data     <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)

lsrm_result <- lsirm2pl_normal_fixed_gamma(data)

# The code following can achieve the same result.
lsirm_result <- lsirm2pl_normal(data, spikenslab = FALSE, fixed_gamma = TRUE)
```

---

lsirm2pl_normal_fixed_gamma_mar

2pl LSIRM model fixing gamma to 1 with normal likelihood for missing at random data.

Description

lsirm2pl_normal_fixed_gamma_mar is used to fit 2pl LSIRM model with gamma fixed to 1 for continuous variable in incomplete data assumed to be missing at random.

lsirm2pl_normal_fixed_gamma_mar factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space, while considering the missing element under the assumption of missing at random. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm2pl_normal_fixed_gamma_mar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001,
  missing = 99
)
```

Arguments

data	Matrix; continuous item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha default value is 1.0.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.

pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; mean of normal prior for beta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

lsirm2pl_normal_fixed_gamma_mar models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$Y_{j,i} = \theta_j + \beta_i - \gamma||z_j - w_i|| + e_{j,i}$$

where the error $e_{j,i} \sim N(0, \sigma^2)$ Under the assumption of missing at random, the model takes the missing element into consideration in the sampling procedure. For the details of missing at random assumption and data augmentation, see References.

Value

lsirm2pl_normal_fixed_gamma_mar returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
sigma_estimate	posterior estimation of standard deviation.
alpha_estimate	posterior estimation of alpha.
z_estimate	posterior estimation of z.
w_estimate	posterior estimation of w.
imp_estimate	
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
sigma	posterior samples of standard deviation.

alpha	posterior samples of alpha.
z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
imp	
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.
accept_alpha	accept ratio of alpha.

Examples

```
# generate example (continuous) item response matrix
data     <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm2pl_normal_fixed_gamma_mar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm2pl_normal(data, spikenslab = FALSE, fixed_gamma = TRUE,
                                missing_data = "mar")
```

---

lsirm2pl_normal_fixed_gamma_mcar

2pl LSIRM model fixing gamma to 1 with normal likelihood for missing completely at random data.

Description

lsirm2pl_normal_fixed_gamma_mcar is used to fit 2pl LSIRM model with gamma fixed to 1 for continuous variable in incomplete data assumed to be missing completely at random.

lsirm2pl_normal_fixed_gamma_mcar factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space, while ignoring the missing element under the assumption of missing completely at random. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm2pl_normal_fixed_gamma_mcar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001,
  missing = 99
)
```

Arguments

data	Matrix; continuous item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha default value is 1.0.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.

pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; mean of normal prior for beta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

lsirm2pl_normal_fixed_gamma_mcar models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$Y_{j,i} = \theta_j + \beta_i - \gamma||z_j - w_i|| + e_{j,i}$$

where the error $e_{j,i} \sim N(0, \sigma^2)$ Under the assumption of missing completely at random, the model ignores the missing element in doing inference. For the details of missing completely at random assumption and data augmentation, see References.

Value

lsirm2pl_normal_fixed_gamma_mcar returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
sigma_estimate	posterior estimation of standard deviation.
alpha_estimate	posterior estimation of alpha.
z_estimate	posterior estimation of z.
w_estimate	posterior estimation of w.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
sigma	posterior samples of standard deviation.
alpha	posterior samples of alpha.

z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.
accept_alpha	accept ratio of alpha.

Examples

```
# generate example (continuous) item response matrix
data     <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm2pl_normal_fixed_gamma_mcar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm2pl_normal(data, spikenslab = FALSE, fixed_gamma = TRUE,
                                missing_data = "mcar")
```

---

lsirm2pl_normal_mar *2pl LSIRM model with normal likelihood and missing at random data.*

Description

lsirm2pl_normal_mar is used to fit 2pl LSIRM model for continuous variable in incomplete data assumed to be missing at random. lsirm2pl_normal_mar factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space, while considering the missing element under the assumption of missing at random. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm2pl_normal_mar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_gamma = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_gamma = 0.5,
  pr_sd_gamma = 1,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001,
  missing = 99
)
```

Arguments

data	Matrix; continuous item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha default value is 1.0.
jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 0.025.

jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_gamma	Numeric; mean of log normal prior for gamma. default value is 0.5.
pr_sd_gamma	Numeric; standard deviation of log normal prior for gamma. default value is 1.0.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; mean of normal prior for beta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

lsirm2pl_normal_mar models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space, with γ represents the weight of the distance term. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$Y_{j,i} = \theta_j + \beta_i - \gamma||z_j - w_i|| + e_{j,i}$$

where the error $e_{j,i} \sim N(0, \sigma^2)$ Under the assumption of missing at random, the model takes the missing element into consideration in the sampling procedure. For the details of missing at random assumption and data augmentation, see References.

Value

lsirm2pl_normal_mar returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
sigma_estimate	posterior estimation of standard deviation.
gamma_estimate	posterior estimation of gamma.
alpha_estimate	posterior estimation of alpha.

imp_estimate	estimation of imputing missing values.
z_estimate	posterior estimation of z.
w_estimate	posterior estimation of w.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
sigma	posterior samples of standard deviation.
gamma	posterior samples of gamma.
alpha	posterior samples of alpha.
imp	imputation for missing Values using posterior samples.
z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.
accept_gamma	accept ratio of gamma.
accept_alpha	accept ratio of alpha.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons.

Examples

```
# generate example (continuous) item response matrix
data     <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm2pl_normal_mar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm2pl_normal(data, spikenslab = FALSE, fixed_gamma = FALSE,
                                missing_data = "mar")
```

lsirm2pl_normal_mar_ss *2pl LSIRM model with normal likelihood and model selection approach for missing at random data.*

Description

lsirm2pl_normal_mar_ss is used to fit 2pl LSIRM model with model selection approach based on spike-and-slab priors for continuous variable in incomplete data assumed to be missing at random. lsirm2pl_normal_mar_ss factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space, while considering the missing element under the assumption of missing at random. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm2pl_normal_mar_ss(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_gamma = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_spike_mean = -3,
  pr_spike_sd = 1,
  pr_slab_mean = 0.5,
  pr_slab_sd = 1,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_xi_a = 0.001,
  pr_xi_b = 0.001,
  missing = 99
```

)

Arguments

data	Matrix; continuous item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha default value is 1.0.
jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 0.025.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_spike_mean	Numeric; mean of spike prior for log gamma default value is -3.
pr_spike_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_slab_mean	Numeric; mean of spike prior for log gamma default value is 0.5.
pr_slab_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; mean of normal prior for beta. default value is 1.0.
pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_xi_a	Numeric; first shape parameter of beta prior for latent variable xi. default value is 1.
pr_xi_b	Numeric; second shape parameter of beta prior for latent variable xi. default value is 1.
missing	Numeric; a number to replace missing values. default value is 99.

Details

`lsirm2pl_normal_mar_ss` models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space, with γ represents the weight of the distance term. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$Y_{j,i} = \theta_j + \beta_i - \gamma||z_j - w_i|| + e_{j,i}$$

where the error $e_{j,i} \sim N(0, \sigma^2)$ Under the assumption of missing at random, the model takes the missing element into consideration in the sampling procedure. For the details of missing at random assumption and data augmentation, see References. `lsirm2pl_normal_mcar_ss` model include model selection approach based on spike-and-slab priors for log gamma. For detail of spike-and-slab priors, see References.

Value

`lsirm2pl_normal_mar_ss` returns an object of list containing the following components:

`beta_estimate`	posterior estimation of beta.
`theta_estimate`	posterior estimation of theta.
`sigma_theta_estimate`	posterior estimation of standard deviation of theta.
`sigma_estimate`	posterior estimation of standard deviation.
`gamma_estimate`	posterior estimation of gamma.
`alpha_estimate`	posterior estimation of alpha.
`z_estimate`	posterior estimation of z.
`w_estimate`	posterior estimation of w.
`pi_estimate`	posterior estimation of phi. inclusion probability of gamma. if estimation of phi is less than 0.5, choose Rasch model with gamma = 0, otherwise latent space model with gamma > 0.
`imp_estimate`	estimation of imputing missing values.
`beta`	posterior samples of beta.
`theta`	posterior samples of theta.
`theta_sd`	posterior samples of standard deviation of theta.
`sigma`	posterior samples of standard deviation.
`gamma`	posterior samples of gamma.
`alpha`	posterior samples of alpha.
`z`	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
`w`	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
`pi`	posterior samples of phi which is indicator of spike and slab prior. If phi is 1, log gamma follows the slab prior, otherwise follows the spike prior.

imp	imputation for missing Values using posterior samples.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.
accept_gamma	accept ratio of gamma.
accept_alpha	accept ratio of alpha.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons. Ishwaran, H., & Rao, J. S. (2005). Spike and slab variable selection: frequentist and Bayesian strategies. The Annals of Statistics, 33(2), 730-773.

Examples

```
# generate example (continuous) item response matrix
data     <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm2pl_normal_mar_ss(data)

# The code following can achieve the same result.
lsirm_result <- lsirm2pl_normal(data, spikenslab = TRUE, fixed_gamma = FALSE,
                                missing_data = "mar")
```

---

lsirm2pl_normal_mcar *2pl LSIRM model with normal likelihood and missing completely at random data.*

Description

lsirm2pl_normal_mcar is used to fit 2pl LSIRM model for continuous variable in incomplete data assumed to be missing completely at random. lsirm2pl_normal_mcar factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space, while ignoring the missing element under the assumption of missing completely at random. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm2pl_normal_mcar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_gamma = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_gamma = 0.5,
  pr_sd_gamma = 1,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001,
  missing = 99
)
```

Arguments

data	Matrix; continuous item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha default value is 1.0.
jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 0.025.

jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_gamma	Numeric; mean of log normal prior for gamma. default value is 0.5.
pr_sd_gamma	Numeric; standard deviation of log normal prior for gamma. default value is 1.0.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; mean of normal prior for beta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.
missing	Numeric; a number to replace missing values. default value is 99.

Details

lsirm2pl_normal_mcar models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space, with γ represents the weight of the distance term. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$Y_{j,i} = \theta_j + \beta_i - \gamma||z_j - w_i|| + e_{j,i}$$

where the error $e_{j,i} \sim N(0, \sigma^2)$ Under the assumption of missing completely at random, the model ignores the missing element in doing inference. For the details of missing completely at random assumption and data augmentation, see References.

Value

lsirm2pl_normal_mcar returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
sigma_estimate	posterior estimation of standard deviation.
gamma_estimate	posterior estimation of gamma.
alpha_estimate	posterior estimation of alpha.

z_estimate	posterior estimation of z.
w_estimate	posterior estimation of w.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
sigma	posterior samples of standard deviation.
gamma	posterior samples of gamma.
alpha	posterior samples of alpha.
z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.
accept_gamma	accept ratio of gamma.
accept_alpha	accept ratio of alpha.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons.

Examples

```
# generate example (continuous) item response matrix
data     <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm2pl_normal_mcar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm2pl_normal(data, spikenslab = FALSE, fixed_gamma = FALSE,
                                missing_data = "mcar")
```

`lsirm2pl_normal_mcar_ss` *2pl LSIRM model with normal likelihood and model selection approach for missing completely at random data.*

Description

lsirm2pl_normal_mcar_ss is used to fit 2pl LSIRM model with model selection approach based on spike-and-slab priors for continuous variable in incomplete data assumed to be missing completely at random. lsirm2pl_normal_mcar_ss factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space, while ignoring the missing element under the assumption of missing completely at random. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm2pl_normal_mcar_ss(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_gamma = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_spike_mean = -3,
  pr_spike_sd = 1,
  pr_slab_mean = 0.5,
  pr_slab_sd = 1,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_xi_a = 0.001,
  pr_xi_b = 0.001,
  missing = 99
```

)

Arguments

data	Matrix; continuous item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha default value is 1.0.
jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 0.025.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_spike_mean	Numeric; mean of spike prior for log gamma default value is -3.
pr_spike_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_slab_mean	Numeric; mean of spike prior for log gamma default value is 0.5.
pr_slab_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; mean of normal prior for beta. default value is 1.0.
pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_xi_a	Numeric; first shape parameter of beta prior for latent variable xi. default value is 1.
pr_xi_b	Numeric; second shape parameter of beta prior for latent variable xi. default value is 1.
missing	Numeric; a number to replace missing values. default value is 99.

Details

`lsirm2pl_normal_mcar_ss` models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space, with γ represents the weight of the distance term. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$Y_{j,i} = \theta_j + \beta_i - \gamma||z_j - w_i|| + e_{j,i}$$

where the error $e_{j,i} \sim N(0, \sigma^2)$ Under the assumption of missing completely at random, the model ignores the missing element in doing inference. For the details of missing completely at random assumption and data augmentation, see References. `lsirm2pl_normal_mcar_ss` model include model selection approach based on spike-and-slab priors for log gamma. For detail of spike-and-slab priors, see References.

Value

`lsirm2pl_normal_mcar_ss` returns an object of list containing the following components:

`beta_estimate`	posterior estimation of beta.
`theta_estimate`	posterior estimation of theta.
`sigma_theta_estimate`	posterior estimation of standard deviation of theta.
`sigma_estimate`	posterior estimation of standard deviation.
`gamma_estimate`	posterior estimation of gamma.
`alpha_estimate`	posterior estimation of alpha.
`z_estimate`	posterior estimation of z.
`w_estimate`	posterior estimation of w.
`pi_estimate`	posterior estimation of phi. inclusion probability of gamma. if estimation of phi is less than 0.5, choose Rasch model with gamma = 0, otherwise latent space model with gamma > 0.
`beta`	posterior samples of beta.
`theta`	posterior samples of theta.
`theta_sd`	posterior samples of standard deviation of theta.
`sigma`	posterior samples of standard deviation.
`gamma`	posterior samples of gamma.
`alpha`	posterior samples of alpha.
`z`	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
`w`	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
`pi`	posterior samples of phi which is indicator of spike and slab prior. If phi is 1, log gamma follows the slab prior, otherwise follows the spike prior.
`accept_beta`	accept ratio of beta.

accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.
accept_gamma	accept ratio of gamma.
accept_alpha	accept ratio of alpha.

References

Little, R. J., & Rubin, D. B. (2019). Statistical analysis with missing data (Vol. 793). John Wiley & Sons. Ishwaran, H., & Rao, J. S. (2005). Spike and slab variable selection: frequentist and Bayesian strategies. The Annals of Statistics, 33(2), 730-773.

Examples

```
# generate example (continuous) item response matrix
data     <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)

# generate example missing indicator matrix
missing_mat     <- matrix(rbinom(500, size = 1, prob = 0.2),ncol=10,nrow=50)

# make missing value with missing indicator matrix
data[missing_mat==1] <- 99

lsirm_result <- lsirm2pl_normal_mcar_ss(data)

# The code following can achieve the same result.
lsirm_result <- lsirm2pl_normal(data, spikenslab = TRUE, fixed_gamma = FALSE,
                                missing_data = "mcar")
```

---

lsirm2pl_normal_o *2pl LSIRM model with normal likelihood*

Description

lsirm2pl_normal_o is used to fit 2pl LSIRM model for continuous variable. lsirm2pl_normal_o factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm2pl_normal_o(
  data,
  ndim = 2,
```

```
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_gamma = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_gamma = 0.5,
  pr_sd_gamma = 1,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001
)
```

Arguments

data	Matrix; continuous item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha default value is 1.0.
jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 0.025.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.

pr_mean_gamma	Numeric; mean of log normal prior for gamma. default value is 0.5.
pr_sd_gamma	Numeric; standard deviation of log normal prior for gamma. default value is 1.0.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; mean of normal prior for beta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.

Details

lsirm2pl_normal_o models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space, with γ represents the weight of the distance term. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$Y_{j,i} = \theta_j + \beta_i - \gamma||z_j - w_i|| + e_{j,i}$$

where the error $e_{j,i} \sim N(0, \sigma^2)$

Value

lsirm2pl_normal_o returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
sigma_estimate	posterior estimation of standard deviation.
gamma_estimate	posterior estimation of gamma.
alpha_estimate	posterior estimation of alpha.
z_estimate	posterior estimation of z.
w_estimate	posterior estimation of w.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
sigma	posterior samples of standard deviation.
gamma	posterior samples of gamma.
alpha	posterior samples of alpha.

z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.
accept_gamma	accept ratio of gamma.
accept_alpha	accept ratio of alpha.

Examples

```
# generate example (continuous) item response matrix
data <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)
lsirm_result <- lsirm2pl_normal_o(data)

# The code following can achieve the same result.
lsirm_result <- lsirm2pl_normal(data)

# The code following can achieve the same result.
lsirm_result <- lsirm2pl_normal(data, spikenslab = FALSE, fixed_gamma = FALSE)
```

---

lsirm2pl_normal_ss *2pl LSIRM model with normal likelihood and model selection approach.*

Description

lsirm2pl_normal_ss is used to fit 2pl LSIRM model for continuous variable with model selection approach. lsirm2pl_normal_ss factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm2pl_normal_ss(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
```

```
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_gamma = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_spike_mean = -3,
  pr_spike_sd = 1,
  pr_slab_mean = 0.5,
  pr_slab_sd = 1,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_xi_a = 0.001,
  pr_xi_b = 0.001
)
```

Arguments

data	Matrix; continuous item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha default value is 1.0.
jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 0.025.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.

pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_spike_mean	Numeric; mean of spike prior for log gamma default value is -3.
pr_spike_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_slab_mean	Numeric; mean of spike prior for log gamma default value is 0.5.
pr_slab_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; mean of normal prior for beta. default value is 1.0.
pr_a_eps	Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.
pr_b_eps	Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_xi_a	Numeric; first shape parameter of beta prior for latent variable xi. default value is 1.
pr_xi_b	Numeric; second shape parameter of beta prior for latent variable xi. default value is 1.

Details

`lsirm2pl_normal_ss` models the continuous value of response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space, with γ represents the weight of the distance term. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$Y_{j,i} = \theta_j + \beta_i - \gamma||z_j - w_i|| + e_{j,i}$$

where the error $e_{j,i} \sim N(0, \sigma^2)$. `lsrm2pl_noraml_ss` model include model selection approach based on spike-and-slab priors for log gamma. For detail of spike-and-slab priors, see References.

Value

`lsirm2pl_normal_ss` returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
sigma_estimate	posterior estimation of standard deviation.
gamma_estimate	posterior estimation of gamma.
alpha_estimate	posterior estimation of alpha.
z_estimate	posterior estimation of z.

w_estimate	posterior estimation of w.
pi_estimate	posterior estimation of phi. inclusion probability of gamma. if estimation of phi is less than 0.5, choose Rasch model with gamma = 0, otherwise latent space model with gamma > 0.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
sigma	posterior samples of standard deviation.
gamma	posterior samples of gamma.
alpha	posterior samples of alpha.
z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
pi	posterior samples of phi which is indicator of spike and slab prior. If phi is 1, log gamma follows the slab prior, otherwise follows the spike prior.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.
accept_gamma	accept ratio of gamma.
accept_alpha	accept ratio of alpha.

References

Ishwaran, H., & Rao, J. S. (2005). Spike and slab variable selection: frequentist and Bayesian strategies. The Annals of Statistics, 33(2), 730-773.

Examples

```
# generate example (continuous) item response matrix
data     <- matrix(rnorm(500, mean = 0, sd = 1),ncol=10,nrow=50)

lsirm_result <- lsirm2pl_normal_ss(data)

# The code following can achieve the same result.
lsirm_result <- lsirm2pl_normal(data, spikenslab = TRUE, fixed_gamma = FALSE)
```

`lsirm2pl_o` *2pl LSIRM model*

Description

lsirm2pl_o is used to fit 2pl LSIRM model. lsirm2pl_o factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm2pl_o(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_gamma = 0.025,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_gamma = 0.5,
  pr_sd_gamma = 1,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001
)
```

Arguments

`data`	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
`ndim`	Numeric; dimension of latent space. default value is 2.
`niter`	Numeric; number of iterations to run MCMC sampling. default value is 15000.
`nburn`	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.

nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha. default value is 1.0.
jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 0.025.
jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_gamma	Numeric; mean of log normal prior for gamma. default value is 0.5.
pr_sd_gamma	Numeric; standard deviation of log normal prior for gamma. default value is 1.0.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; mean of normal prior for beta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.

Details

lsirm2pl_o models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space, with γ represents the weight of the distance term. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$logit(P(Y_{j,i} = 1|\theta_j, \alpha_i, \beta_i, \gamma, z_j, w_i)) = \theta_j * \alpha_i + \beta_i - \gamma||z_j - w_i||$$

Value

lsirm2pl_o returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
gamma_estimate	posterior estimation of gamma.
alpha_estimate	posterior estimation of alpha.
z_estimate	posterior estimation of z.

w_estimate	posterior estimation of w.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
gamma	posterior samples of gamma.
alpha	posterior samples of alpha.
z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.
accept_gamma	accept ratio of gamma.
accept_alpha	accept ratio of alpha.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5),ncol=10,nrow=50)

lsirm_result <- lsirm2pl_o(data)

# The code following can achieve the same result.
lsirm_result <- lsirm2pl(data, spikenslab = FALSE, fixed_gamma = FALSE)
```

---

lsirm2pl_ss *2pl LSIRM model with model selection approach.*

Description

lsirm2pl_ss is used to fit 2pl LSIRM model with model selection approach based on spike-and-slab priors. lsirm2pl_ss factorizes item response matrix into column-wise item effect, row-wise respondent effect and further embeds interaction effect in a latent space. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

Usage

```
lsirm2pl_ss(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_gamma = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_spike_mean = -3,
  pr_spike_sd = 1,
  pr_slab_mean = 0.5,
  pr_slab_sd = 1,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_xi_a = 1,
  pr_xi_b = 1
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
ndim	Numeric; dimension of latent space. default value is 2.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha. default value is 1.0.
jump_gamma	Numeric; jumping rule of the proposal density for gamma. default value is 0.025.

jump_z	Numeric; jumping rule of the proposal density for z. default value is 0.5.
jump_w	Numeric; jumping rule of the proposal density for w. default value is 0.5.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_spike_mean	Numeric; mean of spike prior for log gamma default value is -3.
pr_spike_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_slab_mean	Numeric; mean of spike prior for log gamma default value is 0.5.
pr_slab_sd	Numeric; standard deviation of spike prior for log gamma default value is 1.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; mean of normal prior for beta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_xi_a	Numeric; first shape parameter of beta prior for latent variable xi. default value is 1.
pr_xi_b	Numeric; second shape parameter of beta prior for latent variable xi. default value is 1.

Details

lsirm2pl_ss models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j and the distance between latent position w_i of item i and latent position z_j of respondent j in the shared metric space, with γ represents the weight of the distance term. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$logit(P(Y_{j,i} = 1|\theta_j, \alpha_i, \beta_i, z_j, w_i)) = \theta_j * \alpha_i + \beta_i - \gamma||z_j - w_i||$$

lsirm2pl_ss model include model selection approach based on spike-and-slab priors for log gamma. For detail of spike-and-slab priors, see References.

Value

lsirm2pl_ss returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
gamma_estimate	posterior estimation of gamma.
alpha_estimate	posterior estimation of alpha.
z_estimate	posterior estimation of z.
w_estimate	posterior estimation of w.

pi_estimate	posterior estimation of phi. inclusion probability of gamma. if estimation of phi is less than 0.5, choose Rasch model with gamma = 0, otherwise latent space model with gamma > 0.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
gamma	posterior samples of gamma.
alpha	posterior samples of alpha.
z	posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
w	posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space.
pi	posterior samples of phi which is indicator of spike and slab prior. If phi is 1, log gamma follows the slab prior, otherwise follows the spike prior.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_w	accept ratio of w.
accept_z	accept ratio of z.
accept_gamma	accept ratio of gamma.
accept_alpha	accept ratio of alpha.

References

Ishwaran, H., & Rao, J. S. (2005). Spike and slab variable selection: frequentist and Bayesian strategies. The Annals of Statistics, 33(2), 730-773.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5),ncol=10,nrow=50)

lsirm_result <- lsirm2pl_ss(data)

# The code following can achieve the same result.
 lsirm_result <- lsirm2pl(data, spikenslab = TRUE, fixed_gamma = FALSE)
```

onepl *1pl Rasch model.*

Description

onepl is used to fit 1pl Rasch model.

Usage

```
onepl(
  data,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.
pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.

Details

onepl models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j:

$$logit(P(Y_{j,i} = 1|\theta_j, \beta_i)) = \theta_j + \beta_i$$

Value

onepl returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5),ncol=10,nrow=50)

result <- onepl(data)
```

---

plot_latent *Plotting the latent space of fitted LSIRM model*

Description

plot_latent is used to plot the latent space of fitted LSIRM model.

Usage

```
plot_latent(lsrm_result, rotation = FALSE)
```

Arguments

lsrm_result	List; The output list obtained by any lsrm function.
rotation	Logical; If TRUE the latent positions are visualized after oblique (oblimin) rotation.

Value

plot_latent returns the plot of latent space visualize an interaction map that represents interactions between respondents and items.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5),ncol=10,nrow=50)
lsirm_result <- lsirm1pl(data = data)
plot_latent(lsirm_result)
# use oblique rotation
plot_latent(lsirm_result, rotation = TRUE)
```

---

plot_param *boxplot of parameters of fitted LSIRM model*

Description

plot_param is used to plot the main effect parameters fitted LSIRM model.

Usage

```
plot_param(data, lsrm_result, option, missing = 99)
```

Arguments

data	matrix; binary item response matrix to be analyzed.
lsrm_result	List; The output list obtained by any lsrm function.
option	character; If value is "beta", draw the boxplot for the posterior samples of beta. If value is "theta", draw the distribution of the theta estimates per total test score for the data. If value is "alpha", draw the boxplot for the posterior samples of alpha. The "alpha" is only available for 2pl LSIRM.
missing	Numeric; a number to replace missing values. default value is 99.

Value

plot_param returns the box plot of main effect parameters β_i and θ_j. For item effect β_i, it shows the 95% posterior credible intervals and for respondent effect θ_j, it shows the distribution of the estimates per total sum of positive response.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5),ncol=10,nrow=50)
lsirm_result <- lsirm1pl(data = data)
plot_param(data, lsirm_result, "theta")
plot_param(data, lsirm_result, "beta")
```

TDRI *Inductive Reasoning Developmental Test*

Description

TDRI dataset is the answer to Inductive Reasoning Developmental Test of 1,803 Brazilians with age varying from 5 to 85 years.

Usage

```
data(TDRI)
```

Format

A binary matrix with 1,803 rows and 56 columns.

Details

It presents data from 1,803 Brazilians (52.5% female) with age varying from 5 to 85 years (M = 15.75; SD = 12.21) that answered to the Inductive Reasoning Developmental Test – IRDT, with 56 items designed to assess developmentally sequenced and hierarchically organized inductive reasoning.

Source

https://figshare.com/articles/dataset/TDRI_dataset_csv/3142321

twopl *2pl Rasch model.*

Description

twopl is used to fit 2pl Rasch model. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect.

Usage

```
twopl(
  data,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001
)
```

Arguments

data	Matrix; binary item response matrix to be analyzed. Each row is assumed to be respondent and its column values are assumed to be response to the corresponding item.
niter	Numeric; number of iterations to run MCMC sampling. default value is 15000.
nburn	Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500.
nthin	Numeric;number of thinning, MCMC iterations to discard. default value is 5.
nprint	Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500.
jump_beta	Numeric; jumping rule of the proposal density for beta. default value is 0.4.
jump_theta	Numeric; jumping rule of the proposal density for theta. default value is 1.0.
jump_alpha	Numeric; jumping rule of the proposal density for alpha default value is 1.0.
pr_mean_beta	Numeric; mean of normal prior for beta. default value is 0.
pr_sd_beta	Numeric; standard deviation of normal prior for beta. default value is 1.0.

pr_mean_theta	Numeric; mean of normal prior for theta. default value is 0.
pr_mean_alpha	Numeric; mean of normal prior for alpha. default value is 0.5.
pr_sd_alpha	Numeric; mean of normal prior for beta. default value is 1.0.
pr_a_theta	Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.
pr_b_theta	Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.

Details

twopl models the probability of correct response by respondent j to item i with item effect β_i, respondent effect θ_j. For 2pl model, the the item effect is assumed to have additional discrimination parameter α_i multiplied by θ_j:

$$logit(P(Y_{j,i} = 1|\theta_j, \beta_i, \alpha_i)) = \theta_j * \alpha_i + \beta_i$$

Value

twopl returns an object of list containing the following components:

beta_estimate	posterior estimation of beta.
theta_estimate	posterior estimation of theta.
sigma_theta_estimate	posterior estimation of standard deviation of theta.
alpha_estimate	posterior estimation of alpha.
beta	posterior samples of beta.
theta	posterior samples of theta.
theta_sd	posterior samples of standard deviation of theta.
alpha	posterior samples of alpha.
accept_beta	accept ratio of beta.
accept_theta	accept ratio of theta.
accept_alpha	accept ratio of alpha.

Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5),ncol=10,nrow=50)

result <- twopl(data)
```

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