Package ‘lsirm12pl’

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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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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 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 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.
intrm1pl_mar

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 correspond-
ing 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.
intrm1pl_mar

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 $\beta_i$, respondent effect $\theta_j$ 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

Examples

```r
# 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**

```r
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,
)```
intrm1pl_mcar

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 \( \beta_i \), respondent effect \( \theta_j \) in the shared metric space:

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

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 position of item.
- ls_lambda: posterior samples of lambda which is singular value of decomposition.

References


Examples

```r
# 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

intrm1pl_normal 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.
intrm1pl_normal_mar

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.
intrm1pl_normal_mar

- **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 $\beta_i$, respondent effect $\theta_j$ 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.
intrm1pl_normal_mcar

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

Examples

```r
# 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 = '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

```r
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.
intrm1pl_normal_mcar

Details

intrm1pl_normal_mcar models the continuous value of response by respondent \( j \) to item \( i \) with item effect \( \beta_i \), respondent effect \( \theta_j \) 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 position of respondent.
- **ls_item**: posterior samples of latent position of item.
- **ls_lambda**: posterior samples of lambda which is singular value of decomposition.

References

Examples

```r
# 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

```r
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 \( \beta_i \), respondent effect \( \theta_j \) 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.
intrm1pl_o

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.
intrm1pl_o

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.
intrm1pl_o models the probability of correct response by respondent \( j \) to item \( i \) with item effect \( \beta_i \), respondent effect \( \theta_j \) in the shared metric space:

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

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**

```r
# 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.
intrm2pl_mar

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 \( \beta_i \), respondent effect \( \theta_j \) in the shared metric space. For 2pl model, the the item effect is assumed to have additional discrimination parameter \( \alpha_i \) multiplied by \( \theta_j \):

\[
\text{logit}(P(Y_{j,i} = 1 | \theta_j, \alpha_i, \beta_i, \delta_{j,i})) = \theta_j \cdot \alpha_i + \beta_i + \delta_{j,i}
\]

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.
intrm2pl_mcar

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 position of respondent.

ls_item  
posterior samples of latent position of item.

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

References


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.
l1sirm_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.
intrm2pl_mcar

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_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.
intrm2pl_mcar

**Details**

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

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

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 position of respondent.
- ls_item: posterior samples of latent position of item.
- ls_lambda: posterior samples of lambda which is singular value of decomposition.
intrm2pl_normal

References


Examples

```r
# 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

`intrm2pl_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

`intrm2pl_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**

```r
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_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.
intrm2pl_normal_mar

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

Details

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

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

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


Examples

```r
# 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
```
intrm2pl_normal_mcar

intrm2pl_normal_mcar <- intrm2pl_normal_mar(data)

# The code following can achieve the same result.
intrm2pl_normal_mcar(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 ef-
fect 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 re-
spondent 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 $\beta_i$, respondent effect $\theta_j$ in the shared metric space. For 2pl model, the item effect is assumed to have additional discrimination parameter $\alpha_i$ multiplied by $\theta_j$:

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

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 position of respondent.
- `ls_item` posterior samples of latent position of item.
- `ls_lambda` posterior samples of lambda which is singular value of decomposition.

**References**


**Examples**

```r
# 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 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

```r
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 0.

**pr_mean_theta**  Numeric; mean of normal prior for theta. default value is 0.

**pr_sd_theta**  Numeric; standard deviation 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 0.

**pr_mean_alpha**  Numeric; mean of normal prior for alpha. default value is 0.

**pr_sd_alpha**  Numeric; standard deviation of normal prior for alpha. default value is 0.

**pr_a_theta**  Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 1.

**pr_b_theta**  Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 1.

**pr_a_eps**  Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 1.

**pr_b_eps**  Numeric; scale parameter of inverse gamma prior for variance of data likelihood. default value is 1.

**Details**

intrlm2pl_normal_o models the continuous value of response by respondent \( j \) to item \( i \) with item effect \( \beta_i \), respondent effect \( \theta_j \) in the shared metric space. For 2pl model, the the item effect is assumed to have additional discrimination parameter \( \alpha_i \) multiplied by \( \theta_j \):

\[
Y_{j,i} = \theta_j \times \alpha_i + \beta_i + \delta_{j,i} + e_{j,i}
\]

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**

intrlm2pl_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 position of respondent.
**ls_item**  posterior samples of latent position of item.
**ls_lambda**  posterior samples of lambda which is singular value of decomposition.

**Examples**

```r
# 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.
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 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 0.
intrm2pl_o

- **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 \(\beta_i\), respondent effect \(\theta_j\) in the shared metric space. For 2pl model, the item effect is assumed to have additional discrimination parameter \(\alpha_i\) multiplied by \(\theta_j\):

\[
\text{logit}(P(Y_{j,i} = 1|\theta_j, \beta_i, \alpha_i, \delta_{j,i})) = \theta_j \ast \alpha_i + \beta_i + \delta_{j,i}
\]

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_item**: posterior samples of latent position of item.
- **ls_respondent**: posterior samples of latent position of respondent.
- **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  

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

lsirm1pl  

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.

Value
lsirm1pl returns an object of list. See corresponding function.
### lsirm1pl_fixed_gamma

**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**

```r
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.
**Details**

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

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

**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)

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 $\beta_i$, respondent effect $\theta_j$ 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


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.
lsirm1pl_fixed_gamma_mcar

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_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 $\beta_i$, respondent effect $\theta_j$ and the distance between latent position $w_i$ of item $i$ and latent position $z_j$ of respondent $j$ in the shared metric space:

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

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

Examples

```r
# 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')
```

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

```r
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 \( \beta_i \), respondent effect \( \theta_j \) 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 \( \gamma \) represents the weight of the distance term:

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

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

Examples

```r
# 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

```r
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_sd_theta = 1,
  pr_mean_gamma = 0,
  pr_sd_gamma = 1
)
```
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

1sirm1pl_mar_ss models the probability of correct response by respondent \( j \) to item \( i \) with item effect \( \beta_i \), respondent effect \( \theta_j \), 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 \( \gamma \) represents the weight of the distance term:

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

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. 1sirm1pl_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

1sirm1pl_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 imputing 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


Examples

```r
# 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

```r
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 correspond-
   ing 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 $\beta_i$, respondent effect $\theta_j$ 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 $\gamma$ represents the weight of the distance term:

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

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

Examples

```r
# 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, spikeandslab = FALSE, fixedgamma = FALSE, missingdata = '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

```r
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_sd_theta = 1,
  pr_mean_v = 0,
  pr_sd_v = 1,
  pr_mean_w = 0,
  pr_sd_w = 1,
  pr_mean_z = 0,
  pr_sd_z = 1,
  fixed_gamma = FALSE,
  fixed_beta = FALSE,
  fixed_theta = FALSE
)
```
lsirm1pl_mcar_ss

\[
\begin{align*}
& \text{pr_spike_mean} = -3, \\
& \text{pr_spike_sd} = 1, \\
& \text{pr_slab_mean} = 0.5, \\
& \text{pr_slab_sd} = 1, \\
& \text{pr_a_theta} = 0.001, \\
& \text{pr_b_theta} = 0.001, \\
& \text{pr_xi_a} = 1, \\
& \text{pr_xi_b} = 1, \\
& \text{missing} = 99 \nonumber
\end{align*}
\]

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 $\beta_i$, respondent effect $\theta_j$ 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 $\gamma$ represents the weight of the distance term:

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

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


Examples

```r
# 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

```r
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.
lsirm1pl_normal_fixed_gamma

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

```r
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 corre-
sponding 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 likeli-
hood. 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 \( \beta_i \), respondent effect \( \theta_j \) 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

```r
# 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.
**Details**

`lsirm1pl_normal_fixed_gamma_mar` models the continuous value of response by respondent $j$ to item $i$ with item effect $\beta_i$, respondent effect $\theta_j$ 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 $e_{ji} \sim N(0, \sigma^2)$ 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_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**

```r
# 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 corre-
sponding 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.
lsirm1pl_normal_fixed_gamma_mcar

- **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 $\beta_i$, respondent effect $\theta_j$ 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

```r
# 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

```r
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 corre-
sponding 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 likeli-
hood. 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 $\beta_i$, respondent effect $\theta_j$ 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 $\gamma$ 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

Examples

```r
# 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

```r
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 1.
pr_slab_sd Numeric; standard deviation of spike prior for log gamma default value is 0.5.
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 $\beta_i$, respondent effect $\theta_j$ 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 $\gamma$ 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

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 = 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 = 0.5,
  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.
lsirm1pl_normal_mcar

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 \( \beta_i \), respondent effect \( \theta_j \) 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 \( \gamma \) 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.
**lsirm1pl_normal_mcar_ss**

- **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**


**Examples**

```r
# 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**

*Ipl 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 Ipl 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

```r
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.
lsirm1pl_normal_mcar_ss

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 \(\beta_i\), respondent effect \(\theta_j\) 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 \(\gamma\) 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


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

dsirm1pl_normal_o models the continuous value of response by respondent \( j \) to item \( i \) with item effect \( \beta_i \), respondent effect \( \theta_j \), 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 \( \gamma \) 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

dsirm1pl_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.
### 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.

### Examples

```r
# 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)
```
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.
lsirm1pl_normal_ss

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

Details

`lsirm1pl_normal_ss` models the continuous value of response by respondent $j$ to item $i$ with item effect $\beta_i$, respondent effect $\theta_j$ 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 $\gamma$ 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_normal_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


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)

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_sd_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 $\beta_i$, respondent effect $\theta_j$ 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 $\gamma$ represents the weight of the distance term:

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

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)

---

### 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

```r
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; standard deviation 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 $\beta_i$, respondent effect $\theta_j$ 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 $\gamma$ represents the weight of the distance term:

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

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 representing the dimension of latent space.
- `w` posterior samples of w. The output is 3-dimensional matrix with last axis representing 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


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)
```
### Description

`lsirm2pl` integrates all functions related to 2pl LSIRM

### Usage

```r
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.
**lsirm2pl_fixed_gamma**

**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 $\beta_i$, respondent effect $\theta_j$ 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 $\alpha_i$ multiplied by $\theta_j$:

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

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

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,
lsirm2pl_fixed_gamma_mar

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 \( \beta_i \), respondent effect \( \theta_j \), 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 item effect is assumed to have additional discrimination parameter \( \alpha_i \) multiplied by \( \theta_j \):

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

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 representing the dimension of latent space.
- **w**: posterior samples of w. The output is 3-dimensional matrix with last axis representing 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

Examples

```r
# 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 = "mar")
```

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

```r
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,
```

\begin{verbatim}
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_sd_alpha Numeric; mean of normal prior for alpha. default value is 0.5.
pr_a_theta Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 1.0.
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 \( \beta_i \), respondent effect \( \theta_j \) 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 item effect is assumed to have additional discrimination parameter \( \alpha_i \) multiplied by \( \theta_j \):

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


Examples

```r
# 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

```r
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_sd_theta = 1,
  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 \( \beta_i \), respondent effect \( \theta_j \) in the shared metric space, with \( \gamma \) represents the weight of the distance term. For 2pl model, the item effect is assumed to have additional discrimination parameter \( \alpha_i \) multiplied by \( \theta_j \):

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

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**: 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 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


Examples

```r
# 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 \( \beta_i \), respondent effect \( \theta_j \) in the shared metric space, with \( \gamma \) represents the weight of the distance term. For 2pl model, the item effect is assumed to have additional discrimination parameter \( \alpha_i \) multiplied by \( \theta_j \):

\[
\text{logit}(P(Y_{j,i} = 1|\theta_j, \alpha_i, \beta_i, \gamma, z_j, w_i)) = \theta_j \ast \alpha_i + \beta_i - \gamma ||z_j - w_i||
\]

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: 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: 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.
- pi: posterior estimation of phi.
- 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


Examples

```r
# 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 = 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

```r
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.
**Details**

`lsirm2pl_mcar` models the probability of correct response by respondent $j$ to item $i$ with item effect $\beta_i$, respondent effect $\theta_j$ in the shared metric space, with $\gamma$ represents the weight of the distance term. For 2pl model, the item effect is assumed to have additional discrimination parameter $\alpha_i$ multiplied by $\theta_j$:

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

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


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

```r
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 \( \beta_i \), respondent effect \( \theta_j \) in the shared metric space, with \( \gamma \) represents the weight of the distance term. For 2pl model, the the item effect is assumed to have additional discrimination parameter \( \alpha_i \) multiplied by \( \theta_j \):

\[
\text{logit}(P(Y_{j,i} = 1|\theta_j, \alpha_i, \beta_i, \gamma, z_j, w_i)) = \theta_j \cdot \alpha_i + \beta_i - \gamma ||z_j - w_i||
\]

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


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")

## Description

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

## Usage

```r
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_mar_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**

```r
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.
lsirm2pl_normal_fixed_gamma models the continuous value of response by respondent \( j \) to item \( i \) with item effect \( \beta_i \), respondent effect \( \theta_j \) 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 item effect is assumed to have additional discrimination parameter \( \alpha_i \) multiplied by \( \theta_j \):

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

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 representing the dimension of latent space.
w            posterior samples of w. The output is 3-dimensional matrix with last axis representing 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)
lsirm_result <- lsirm2pl_normal_fixed_gamma(data)

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

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.
**lsirm2pl_normal_fixed_gamma_mar**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>pr_mean_theta</td>
<td>Numeric; mean of normal prior for theta. default value is 0.</td>
</tr>
<tr>
<td>pr_mean_alpha</td>
<td>Numeric; mean of normal prior for alpha. default value is 0.5.</td>
</tr>
<tr>
<td>pr_sd_alpha</td>
<td>Numeric; mean of normal prior for beta. default value is 1.0.</td>
</tr>
<tr>
<td>pr_a_theta</td>
<td>Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001.</td>
</tr>
<tr>
<td>pr_b_theta</td>
<td>Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001.</td>
</tr>
<tr>
<td>pr_a_eps</td>
<td>Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.</td>
</tr>
<tr>
<td>pr_b_eps</td>
<td>Numeric; scale parameter of inverse gamma prior for variance of data likelihood. default value is 0.001.</td>
</tr>
<tr>
<td>missing</td>
<td>Numeric; a number to replace missing values. default value is 99.</td>
</tr>
</tbody>
</table>

**Details**

`lsirm2pl_normal_fixed_gamma_mar` models the continuous value of response by respondent $j$ to item $i$ with item effect $\beta_i$, respondent effect $\theta_j$ 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 item effect is assumed to have additional discrimination parameter $\alpha_i$ multiplied by $\theta_j$:

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

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_mcar(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 corre-
sponding 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.
Details

lsirm2pl_normal_fixed_gamma_mcar models the continuous value of response by respondent \( j \) to item \( i \) with item effect \( \beta_i \), respondent effect \( \theta_j \) 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 item effect is assumed to have additional discrimination parameter \( \alpha_i \) multiplied by \( \theta_j \):

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

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.
Posterior samples of z. The output is 3-dimensional matrix with last axis representing the dimension of latent space.

Posterior samples of w. The output is 3-dimensional matrix with last axis representing the dimension of latent space.

Accept ratio of beta.

Accept ratio of theta.

Accept ratio of w.

Accept ratio of z.

Accept ratio of alpha.

Examples

```r
# 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")
```

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

```r
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 corre-
sponding 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.
lsirm2pl_normal_mar

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 \( \beta_i \), respondent effect \( \theta_j \) 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 \( \gamma \) represents the weight of the distance term. For 2pl model, the the item effect is assumed to have additional discrimination parameter \( \alpha_i \) multiplied by \( \theta_j \):

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

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


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

```r
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 \( \beta_i \), respondent effect \( \theta_j \) 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 \( \gamma \) represents the weight of the distance term. For 2pl model, the the item effect is assumed to have additional discrimination parameter \( \alpha_i \) multiplied by \( \theta_j \):

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

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.
**\texttt{lsirm2pl_normal_mcar}**

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

**Description**

\texttt{lsirm2pl_normal_mcar} is used to fit 2pl LSIRM model for continuous variable in incomplete data assumed to be missing completely at random. \texttt{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

```r
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
)
```
lsirm2pl_normal_mcar

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 $\beta_i$, respondent effect $\theta_j$ 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 $\gamma$ represents the weight of the distance term. For 2pl model, the the item effect is assumed to have additional discrimination parameter $\alpha_i$ multiplied by $\theta_j$:

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

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

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 \( \beta_i \), respondent effect \( \theta_j \) 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 \( \gamma \) represents the weight of the distance term. For 2pl model, the item effect is assumed to have additional discrimination parameter \( \alpha_i \) multiplied by \( \theta_j \):

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

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


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 factors 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 $\beta_i$, respondent effect $\theta_j$ 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 $\gamma$ represents the weight of the distance term. For 2pl model, the the item effect is assumed to have additional discrimination parameter $\alpha_i$ multiplied by $\theta_j$:

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

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.
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)

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_spikes_mean = -3,
pr_spikes_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 0.5.
pr_sd_beta Numeric; standard deviation of normal prior for beta. default value is 1.0.
lsirm2pl_normal_ss

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

Details

lsirm2pl_normal_ss models the continuous value of response by respondent \( j \) to item \( i \) with item effect \( \beta_i \), respondent effect \( \theta_j \) 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 \( \gamma \) represents the weight of the distance term. For 2pl model, the the item effect is assumed to have additional discrimination parameter \( \alpha_i \) multiplied by \( \theta_j \):

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

where the error \( e_{j,i} \sim N(0, \sigma^2) \). lsirm2pl_normal_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

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_sd_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 \( \beta_i \), respondent effect \( \theta_j \) 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 \( \gamma \) represents the weight of the distance term. For 2pl model, the the item effect is assumed to have additional discrimination parameter \( \alpha_i \) multiplied by \( \theta_j \):

\[
\text{logit}(P(Y_{j,i} = 1 \mid \theta_j, \alpha_i, \beta_i, \gamma, z_j, w_i)) = \theta_j \cdot \alpha_i + \beta_i - \gamma ||z_j - w_i||
\]

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.
lsirm2pl_ss

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 1.
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 \( \beta_i \), respondent effect \( \theta_j \) 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 \( \gamma \) represents the weight of the distance term. For 2pl model, the the item effect is assumed to have additional discrimination parameter \( \alpha_i \) multiplied by \( \theta_j \):

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

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


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

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 \( \beta_i \), respondent effect \( \theta_j \):

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

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

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

result <- onepl(data)
```

Description

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

Usage

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

Examples

```r
# 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 returns the box plot of main effect parameters $\beta_i$ and $\theta_j$. For item effect $\beta_i$, it shows the 95% posterior credible intervals and for respondent effect $\theta_j$, it shows the distribution of the estimates per total sum of positive response.

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.

missing Numeric; a number to replace missing values. default value is 99.
Examples

```r
# 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**

```r
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](https://figshare.com/articles/dataset/TDRI_dataset_csv/3142321)
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

```r
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 1.0.)
- `pr_sd_alpha` (Numeric; standard deviation of normal prior for alpha. default value is 1.0.)
- `pr_a_theta` (Numeric; standard deviation of normal prior for a_theta. default value is 0.001.)
- `pr_b_theta` (Numeric; standard deviation of normal prior for b_theta. default value is 0.001.)
twopl

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>pr_mean_theta</td>
<td>Numeric; mean of normal prior for theta. default value is 0.</td>
</tr>
<tr>
<td>pr_mean_alpha</td>
<td>Numeric; mean of normal prior for alpha. default value is 0.5.</td>
</tr>
<tr>
<td>pr_sd_alpha</td>
<td>Numeric; mean of normal prior for beta. default value is 1.0.</td>
</tr>
<tr>
<td>pr_a_theta</td>
<td>Numeric; shape parameter of inverse gamma prior for variance of theta.</td>
</tr>
<tr>
<td>pr_b_theta</td>
<td>Numeric; scale parameter of inverse gamma prior for variance of theta.</td>
</tr>
</tbody>
</table>

**Details**

twopl models the probability of correct response by respondent \( j \) to item \( i \) with item effect \( \beta_i \), respondent effect \( \theta_j \). For 2pl model, the item effect is assumed to have additional discrimination parameter \( \alpha_i \) multiplied by \( \theta_j \): 

\[
\text{logit}(P(Y_{j,i} = 1|\theta_j, \beta_i)) = \theta_j \ast \alpha_i + \beta_i
\]

**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**

```r
# 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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