# Package 'lsirm12pl'

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**Type** Package

**Title** Latent Space Item Response Model

**Version** 1.3.1

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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.

**License** GPL-3

**Imports** Rcpp (>= 1.0.5), MCMCpack, ggplot2, GPArotation, dplyr, grDevices, rlang, pROC, coda, spatstat, spatstat.geom, spatstat.random, plotly, grid, gridExtra, fpc, kernlab

**LinkingTo** Rcpp, RcppArmadillo

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**Suggests** knitr, testthat

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**LazyData** true

**NeedsCompilation** yes

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BFPT                          *Big Five Personality Test*

---

#### Description

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

#### Usage

```
data(BFPT)
```

#### Format

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

#### Details

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

#### Source

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

---

diagnostic                    *Diagnostic the result of LSIRM model*

---

#### Description

`diagnostic` is used to diagnostic the result of LSIRM model.

**Usage**

```
diagnostic(
  object,
  plot = TRUE,
  draw.item = list(beta = "first", theta = "first", alpha = "second"),
  which.draw = c("beta", "gamma")
)
```

**Arguments**

| | |
|---|---|
| `object` | object of class `lsirm`. |
| `plot` | If TRUE, MCMC diagnostic plots are returned |
| `draw.item` | Select items for diagnosis. A default "first" is drawing the first item for selected parameters in `which.draw`. Parameter "alpha", however, uses "second" as a default value because the first alpha has an estimation issue. Positions and item names are supported. For instance, if the name of item is "i1", "i2", "i3" and its positions is in order, the result of beta = c("i1","i2","i3") and beta = c(1,2,3) are equivalent. |
| `which.draw` | Select parameters for diagnosis. For the 1PL model, "beta", "theta" and "gamma" are available. "alpha" is only available in the 2PL model. |

**Value**

`diagnostic` returns plots for checking MCMC convergence for selected parameters.

**Examples**

```
# generate example item response matrix
data      <- matrix(rbinom(500, size = 1, prob = 0.5), ncol=10, nrow=50)
lsirm_result <- lsirm(data ~ lsirm1pl(spikenslab = FALSE, fixed_gamma = FALSE))

# 1PL model
diagnostic(lsirm_result, plot=TRUE,
           which.draw=c("beta","theta","gamma"))

# 1PL model, multiple items
diagnostic(lsirm_result, plot=TRUE, draw.item=list(beta = c(1,2,3)),
           which.draw=c("beta", "gamma"))

lsirm_result <- lsirm(data ~ lsirm2pl(spikenslab = FALSE, fixed_gamma = FALSE))

# 2PL model
diagnostic(lsirm_result, plot=TRUE,
           which.draw=c("beta", "theta", "alpha", "gamma"))
```

---

gof                        *Goodness-of-fit LSIRM model*

---

### Description

gof is goodness-of-fit the latent space of fitted LSIRM model.

### Usage

```
gof(object, nsim = 500)
```

### Arguments

| | |
|---|---|
| object | object of class lsirm. |
| nsim | Integer; Number of simulation. Default is 500 |

### Value

gof returns the boxplot or AUC plot

### Examples

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5),ncol=10,nrow=50)
lsirm_result <- lsirm(data ~ lsirm1pl(spikenslab = FALSE, fixed_gamma = FALSE))
gof(lsirm_result)
```

---

lsirm                      *Fit a LSIRM model*

---

### Description

lsirm is used to fit 1PL LSIRM and 2PL LSIRM using Bayesian method as described in Jeon et al. (2021).

### Usage

```
lsirm(data, ...)
```

### Arguments

| | |
|---|---|
| data | Matrix; binary or 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. |
| ... | Additional arguments for the corresponding function. |

## Value

lsirm returns an object of list. See corresponding function.

## See Also

lsirm1pl and lsirm2pl

---

lsirm.formula                    *Formula function for LSIRM model*

---

## Description

lsirm.formula is formula object.

## Usage

```
## S3 method for class 'formula'
lsirm(formula, ...)
```

## Arguments

formula          The form of formula is lsirm(A ~ <term 1>(<term 2> + <term 3> ...)), where
                 A is binary or continuous item response matrix to be analyzed, <term1> is the
                 model you want to fit and has one of the following values: "lsirm1pl" and
                 "lsirm2pl"., and <term 2>, <term 3>, etc., are each option for the model.

...              Additional arguments for the corresponding function.

---

lsirm12pl                        *lsirm12pl-package*

---

## 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 con-
tinuous 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 param-
eters.

---

lsirm1pl                          *Fit a 1pl LSIRM model*

---

#### Description

[lsirm1pl](lsirm1pl) integrates all functions related to 1pl LSIRM

#### Usage

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

#### Arguments

| | |
|---|---|
| data | Matrix; binary or 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. |
| spikenslab | Whether to use a model selection approach. |
| fixed_gamma | Whether fix gamma to 1. |
| missing_data | The assumed missing type. One of NA, "mar" and "mcar". Default uses NA. |
| ... | Additional arguments for the corresponding function. |

#### Value

lsirm1pl returns an object of list. See corresponding function.

#### Note

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

#### See Also

[lsirm1pl_o](lsirm1pl_o), [lsirm1pl_fixed_gamma](lsirm1pl_fixed_gamma), [lsirm1pl_mar](lsirm1pl_mar), [lsirm1pl_mcar](lsirm1pl_mcar),[lsirm1pl_fixed_gamma_mar](lsirm1pl_fixed_gamma_mar), [lsirm1pl_fixed_gamma_mcar](lsirm1pl_fixed_gamma_mcar), [lsirm1pl_ss](lsirm1pl_ss), [lsirm1pl_mar_ss](lsirm1pl_mar_ss), [lsirm1pl_mcar_ss](lsirm1pl_mcar_ss), [lsirm1pl_normal_o](lsirm1pl_normal_o), [lsirm1pl_normal_fixed_gamma](lsirm1pl_normal_fixed_gamma), [lsirm1pl_normal_mar](lsirm1pl_normal_mar), [lsirm1pl_normal_mcar](lsirm1pl_normal_mcar),[lsirm1pl_normal_fixed_gamma_mar](lsirm1pl_normal_fixed_gamma_mar), [lsirm1pl_normal_fixed_gamma_mcar](lsirm1pl_normal_fixed_gamma_mcar), [lsirm1pl_normal_ss](lsirm1pl_normal_ss), [lsirm1pl_normal_mar_ss](lsirm1pl_normal_mar_ss), [lsirm1pl_normal_mcar_ss](lsirm1pl_normal_mcar_ss)

---

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

---

### Description

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

### Usage

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

### 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. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

### 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:

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

### Value

lsirm1pl_fixed_gamma returns an object of list containing the following components:

| | |
|---|---|
| data | data frame or matrix containing the variables in the model. |
| bic | Numeric value with the corresponding BIC. |
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| 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 <- lsirm(data ~ lsirm1pl(spikenslab = FALSE, fixed_gamma = TRUE))
```

---

lsirm1pl_fixed_gamma_mar

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

---

## Description

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

## Usage

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

## 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.val | Numeric; a number to replace missing values. default value is 99. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

## 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:

| | |
|---|---|
| data | data frame or matrix containing the variables in the model. |
| missing.val | a number to replace missing values. |

| | |
|---|---|
| bic | Numeric value with the corresponding BIC. |
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| beta_estimate | posterior estimation of beta. |
| theta_estimate | posterior estimation of theta. |
| sigma_theta_estimate | |
| | posterior estimation of standard deviation of theta. |
| z_estimate | posterior estimation of z. |
| w_estimate | posterior estimation of w. |
| imp_estimate | probability of imputating a missing value with 1. |
| beta | posterior samples of beta. |
| theta | posterior samples of theta. |
| theta_sd | posterior samples of standard deviation of theta. |
| z | posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| w | posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| imp | imputation for missing Values using posterior samples. |
| accept_beta | accept ratio of beta. |
| accept_theta | accept ratio of theta. |
| accept_w | accept ratio of w. |
| accept_z | accept ratio of z. |

### References

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

### Examples

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

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

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

lsirm_result <- lsirm1pl_fixed_gamma_mar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm(data ~ lsirm1pl(spikenslab = FALSE, fixed_gamma = TRUE,
missing_data = "mar", missing.val = 99))
```

---

```
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 inter-
action 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 inter-
actions 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.val = 99,
  verbose = FALSE
)
```

### 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.val | Numeric; a number to replace missing values. default value is 99. |
| verbose | Logical; If TRUE, MCMC samples are printed for each `nprint`. default value is FALSE |

### 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:

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

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:

| data | data frame or matrix containing the variables in the model. |
|---|---|
| missing.val | a number to replace missing values. |
| bic | Numeric value with the corresponding BIC. |
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| beta_estimate | posterior estimation of beta. |
| theta_estimate | posterior estimation of theta. |
| sigma_theta_estimate | |
| | posterior estimation of standard deviation of theta. |
| z_estimate | posterior estimation of z. |

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

### References

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

### Examples

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

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

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

lsirm_result <- lsirm1pl_fixed_gamma_mcar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm(data ~ lsirm1pl(spikenslab = FALSE, fixed_gamma = TRUE,
missing_data = "mcar", missing.val = 99))
```

---

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

---

### Description

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

**Usage**

```
lsirm1pl_mar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_gamma = 0.025,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_gamma = 0.5,
  pr_sd_gamma = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  missing.val = 99,
  verbose = FALSE
)
```

**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.val | Numeric; a number to replace missing values. default value is 99. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

### 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:

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

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:

| | |
|---|---|
| data | data frame or matrix containing the variables in the model. |
| missing.val | a number to replace missing values. |
| bic | Numeric value with the corresponding BIC. |
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| beta_estimate | posterior estimation of beta. |
| theta_estimate | posterior estimation of theta. |
| sigma_theta_estimate | |
| | posterior estimation of standard deviation of theta. |
| gamma_estimate | posterior estimation of gamma. |
| z_estimate | posterior estimation of z. |
| w_estimate | posterior estimation of w. |
| imp_estimate | probability of imputating a missing value with 1. |
| beta | posterior samples of beta. |
| theta | posterior samples of theta. |

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

### References

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

### Examples

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

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

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

lsirm_result <- lsirm1pl_mar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm(data ~ lsirm1pl(spikenslab = FALSE, fixed_gamma = FALSE,
missing_data ='mar', missing.val = 99))
```

---

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

---

### Description

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

### Usage

```
lsirm1pl_mar_ss(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_gamma = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_spike_mean = -3,
  pr_spike_sd = 1,
  pr_slab_mean = 0.5,
  pr_slab_sd = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_xi_a = 1,
  pr_xi_b = 1,
  missing.val = 99,
  verbose = FALSE
)
```

### 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.val | Numeric; a number to replace missing values. default value is 99. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

## Details

lsirm1pl_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:

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

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

## Value

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

| | |
|---|---|
| `data` | data frame or matrix containing the variables in the model. |
| `missing.val` | a number to replace missing values. |
| `bic` | Numeric value with the corresponding BIC. |
| `mcmc_inf` | number of mcmc iteration, burn-in periods, and thinning intervals. |
| `map_inf` | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| `beta_estimate` | posterior estimation of beta. |
| `theta_estimate` | posterior estimation of theta. |
| `sigma_theta_estimate` | |
| | posterior estimation of standard deviation of theta. |
| `gamma_estimate` | posterior estimation of gamma. |
| `z_estimate` | posterior estimation of z. |
| `w_estimate` | posterior estimation of w. |
| `pi_estimate` | posterior estimation of phi. inclusion probability of gamma. if estimation of phi is less than 0.5, choose Rasch model with gamma = 0, otherwise latent space model with gamma > 0. |
| `imp_estimate` | probability of imputating a missing value with 1. |
| `beta` | posterior samples of beta. |
| `theta` | posterior samples of theta. |
| `theta_sd` | posterior samples of standard deviation of theta. |
| `gamma` | posterior samples of gamma. |
| `z` | posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| `w` | posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| `pi` | posterior samples of phi which is indicator of spike and slab prior. If phi is 1, log gamma follows the slab prior, otherwise follows the spike prior. |
| `imp` | imputation for missing Values using posterior samples. |
| `accept_beta` | accept ratio of beta. |
| `accept_theta` | accept ratio of theta. |
| `accept_w` | accept ratio of w. |
| `accept_z` | accept ratio of z. |
| `accept_gamma` | accept ratio of gamma. |

## References

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

## Examples

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

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

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

lsirm_result <- lsirm1pl_mar_ss(data)

# The code following can achieve the same result.
lsirm_result <- lsirm(data ~ lsirm1pl(spikenslab = TRUE, fixed_gamma = FALSE,
missing_data = 'mar', missing = 99))
```

---

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

---

### Description

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

### Usage

```
lsirm1pl_mcar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_gamma = 0.025,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_gamma = 0.5,
  pr_sd_gamma = 1,
```

```
    pr_a_theta = 0.001,
    pr_b_theta = 0.001,
    missing.val = 99,
    verbose = FALSE
)
```

## 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.val | Numeric; a number to replace missing values. default value is 99. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

## 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:

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

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:

| | |
|---|---|
| `data` | data frame or matrix containing the variables in the model. |
| `missing.val` | a number to replace missing values. |
| `bic` | Numeric value with the corresponding BIC. |
| `mcmc_inf` | number of mcmc iteration, burn-in periods, and thinning intervals. |
| `map_inf` | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| `beta_estimate` | posterior estimation of beta. |
| `theta_estimate` | posterior estimation of theta. |
| `sigma_theta_estimate` | |
| | posterior estimation of standard deviation of theta. |
| `gamma_estimate` | posterior estimation of gamma. |
| `z_estimate` | posterior estimation of z. |
| `w_estimate` | posterior estimation of w. |
| `beta` | posterior samples of beta. |
| `theta` | posterior samples of theta. |
| `theta_sd` | posterior samples of standard deviation of theta. |
| `gamma` | posterior samples of gamma. |
| `z` | posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| `w` | posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| `accept_beta` | accept ratio of beta. |
| `accept_theta` | accept ratio of theta. |
| `accept_z` | accept ratio of z. |
| `accept_w` | accept ratio of w. |
| `accept_gamma` | accept ratio of gamma. |

## References

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

## Examples

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

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

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

lsirm_result <- lsirm1pl_mcar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm(data ~ lsirm1pl(spikenslab = FALSE, fixed_gamma = FALSE,
missing_data ='mcar', missing.val = 99))
```

---

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

---

## Description

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

## Usage

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

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

## 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.val` | Numeric; a number to replace missing values. default value is 99. |
| `verbose` | Logical; If TRUE, MCMC samples are printed for each `nprint`. default value is FALSE |

### 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:

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

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:

| | |
|---|---|
| `data` | data frame or matrix containing the variables in the model. |
| `missing.val` | a number to replace missing values. |
| `bic` | Numeric value with the corresponding BIC. |
| `mcmc_inf` | number of mcmc iteration, burn-in periods, and thinning intervals. |
| `map_inf` | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| `beta_estimate` | posterior estimation of beta. |
| `theta_estimate` | posterior estimation of theta. |
| `sigma_theta_estimate` | |
| | posterior estimation of standard deviation of theta. |
| `gamma_estimate` | posterior estimation of gamma. |
| `z_estimate` | posterior estimation of z. |
| `w_estimate` | posterior estimation of w. |
| `pi_estimate` | posterior estimation of phi. inclusion probability of gamma. if estimation of phi is less than 0.5, choose Rasch model with gamma = 0, otherwise latent space model with gamma > 0. |
| `beta` | posterior samples of beta. |
| `theta` | posterior samples of theta. |
| `theta_sd` | posterior samples of standard deviation of theta. |
| `gamma` | posterior samples of gamma. |
| `z` | posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |

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

## References

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

## Examples

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

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

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

lsirm_result <- lsirm1pl_mcar_ss(data)

# The code following can achieve the same result.
lsirm_result <- lsirm(data ~ lsirm1pl(spikenslab = TRUE, fixed_gamma = FALSE,
missing_data ='mcar', missing.val = 99))
```

---

| lsirm1pl_normal | *1pl LSIRM model with normal likelihood* |
|---|---|

## Description

[lsirm1pl_normal](#) integrates all functions related to 1pl LSIRM with normal likelihood using multiplicative effect.

**Usage**

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

**Arguments**

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

**Value**

lsirm1pl_normal returns an object of list. See corresponding function.

**Note**

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

**See Also**

[lsirm1pl_normal_o](), [lsirm1pl_normal_fixed_gamma](), [lsirm1pl_normal_mar](),
[lsirm1pl_normal_mcar](), [lsirm1pl_normal_fixed_gamma_mar](), [lsirm1pl_normal_fixed_gamma_mcar](),
[lsirm1pl_normal_ss](), [lsirm1pl_normal_mar_ss](), [lsirm1pl_normal_mcar_ss]()

---

lsirm1pl_normal_fixed_gamma

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

---

**Description**

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

**Usage**

```
lsirm1pl_normal_fixed_gamma(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001,
  verbose = FALSE
)
```

**Arguments**

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

| | |
|---|---|
| pr_b_theta | Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001. |
| pr_a_eps | Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001. |
| pr_b_eps | Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

### 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:

| | |
|---|---|
| data | data frame or matrix containing the variables in the model. |
| bic | Numeric value with the corresponding BIC. |
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| beta_estimate | posterior estimation of beta. |
| theta_estimate | posterior estimation of theta. |
| sigma_theta_estimate | |
| | posterior estimation of standard deviation of theta. |
| sigma_estimate | posterior estimation of standard deviation. |
| z_estimate | posterior estimation of z. |
| w_estimate | posterior estimation of w. |
| beta | posterior samples of beta. |
| theta | posterior samples of theta. |
| theta_sd | posterior samples of standard deviation of theta. |
| sigma | posterior samples of standard deviation. |
| z | posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| w | posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| accept_beta | accept ratio of beta. |
| accept_theta | accept ratio of theta. |
| accept_w | accept ratio of w. |
| accept_z | accept ratio of z. |

### Examples

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

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

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

lsirm_result <- lsirm1pl_normal_fixed_gamma(data)

# The code following can achieve the same result.
lsirm_result <- lsirm(data ~ lsirm1pl(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.val = 99,
      verbose = FALSE
)
```

## Arguments

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

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

**Value**

`lsirm1pl_normal_fixed_gamma_mar` returns an object of list containing the following components:

| | |
|---|---|
| `data` | data frame or matrix containing the variables in the model. |
| `missing.val` | a number to replace missing values. |
| `bic` | Numeric value with the corresponding BIC. |
| `mcmc_inf` | number of mcmc iteration, burn-in periods, and thinning intervals. |
| `map_inf` | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| `beta_estimate` | posterior estimation of beta. |
| `theta_estimate` | posterior estimation of theta. |
| `sigma_theta_estimate` | |
| | posterior estimation of standard deviation of theta. |
| `sigma_estimate` | posterior estimation of standard deviation. |
| `z_estimate` | posterior estimation of z. |
| `w_estimate` | posterior estimation of w. |
| `imp_estimate` | estimation of imputing missing values. |
| `beta` | posterior samples of beta. |
| `theta` | posterior samples of theta. |
| `theta_sd` | posterior samples of standard deviation of theta. |
| `sigma` | posterior samples of standard deviation. |
| `z` | posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| `w` | posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| `imp` | imputation for missing Values using posterior samples. |
| `accept_beta` | accept ratio of beta. |
| `accept_theta` | accept ratio of theta. |
| `accept_w` | accept ratio of w. |
| `accept_z` | accept ratio of z. |

## Examples

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

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

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

lsirm_result <- lsirm1pl_normal_fixed_gamma_mar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm(data ~ lsirm1pl(spikenslab = FALSE, fixed_gamma = TRUE,
missing_data = "mar", missing.val = 99))
```

---

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.val = 99,
  verbose = FALSE
)
```

## Arguments

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

## 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:

> | | |
> |---|---|
> | `data` | data frame or matrix containing the variables in the model. |
> | `missing.val` | a number to replace missing values. |
> | `bic` | Numeric value with the corresponding BIC. |
> | `mcmc_inf` | number of mcmc iteration, burn-in periods, and thinning intervals. |
> | `map_inf` | value of log maximum a posterior and iteration number which have log maximum a posterior. |
> | `beta_estimate` | posterior estimation of beta. |
> | `theta_estimate` | posterior estimation of theta. |
> | `sigma_theta_estimate` | |
> | | posterior estimation of standard deviation of theta. |
> | `sigma_estimate` | posterior estimation of standard deviation. |
> | `z_estimate` | posterior estimation of z. |
> | `w_estimate` | posterior estimation of w. |
> | `beta` | posterior samples of beta. |
> | `theta` | posterior samples of theta. |
> | `theta_sd` | posterior samples of standard deviation of theta. |
> | `sigma` | posterior samples of standard deviation. |
> | `z` | posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
> | `w` | posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
> | `accept_beta` | accept ratio of beta. |
> | `accept_theta` | accept ratio of theta. |
> | `accept_w` | accept ratio of w. |
> | `accept_z` | accept ratio of z. |

**Examples**

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

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

# make missing value with missing indicator matrix
```

```
data[missing_mat==1] <- 99

lsirm_result <- lsirm1pl_normal_fixed_gamma_mcar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm(data ~ lsirm1pl(spikenslab = FALSE, fixed_gamma = TRUE,
missing_data = "mcar", missing.val = 99))
```

---

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

---

### Description

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

### Usage

```
lsirm1pl_normal_mar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_gamma = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_gamma = 0.5,
  pr_sd_gamma = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  pr_a_eps = 0.001,
  pr_b_eps = 0.001,
  missing.val = 99,
  verbose = FALSE
)
```

## Arguments

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

## 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:

| | |
|---|---|
| `data` | data frame or matrix containing the variables in the model. |
| `missing.val` | a number to replace missing values. |
| `bic` | Numeric value with the corresponding BIC. |
| `mcmc_inf` | number of mcmc iteration, burn-in periods, and thinning intervals. |
| `map_inf` | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| `beta_estimate` | posterior estimation of beta. |
| `theta_estimate` | posterior estimation of theta. |
| `sigma_theta_estimate` | |
| | posterior estimation of standard deviation of theta. |
| `sigma_estimate` | posterior estimation of standard deviation. |
| `gamma_estimate` | posterior estimation of gamma. |
| `z_estimate` | posterior estimation of z. |
| `w_estimate` | posterior estimation of w. |
| `imp_estimate` | estimation of imputing missing values. |
| `beta` | posterior samples of beta. |
| `theta` | posterior samples of theta. |
| `theta_sd` | posterior samples of standard deviation of theta. |
| `sigma` | posterior samples of standard deviation. |
| `gamma` | posterior samples of gamma. |
| `z` | posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| `w` | posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| `imp` | imputation for missing Values using posterior samples. |
| `accept_beta` | accept ratio of beta. |
| `accept_theta` | accept ratio of theta. |
| `accept_w` | accept ratio of w. |
| `accept_z` | accept ratio of z. |
| `accept_gamma` | accept ratio of gamma. |

### References

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

## Examples

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

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

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

lsirm_result <- lsirm1pl_normal_mar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm(data ~ lsirm1pl(spikenslab = FALSE, fixed_gamma = FALSE,
missing_data ='mar', missing.val = 99))
```

---

lsirm1pl_normal_mar_ss

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

---

## Description

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

## Usage

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

```
    pr_spike_mean = -3,
    pr_spike_sd = 1,
    pr_slab_mean = 0.5,
    pr_slab_sd = 1,
    pr_a_theta = 0.001,
    pr_b_theta = 0.001,
    pr_a_eps = 0.001,
    pr_b_eps = 0.001,
    pr_xi_a = 0.001,
    pr_xi_b = 0.001,
    missing.val = 99,
    verbose = FALSE
)
```

## Arguments

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

| pr_a_eps | Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001. |
|---|---|
| pr_b_eps | Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001. |
| pr_xi_a | Numeric; first shape parameter of beta prior for latent variable xi. default value is 1. |
| pr_xi_b | Numeric; second shape parameter of beta prior for latent variable xi. default value is 1. |
| missing.val | Numeric; a number to replace missing values. default value is 99. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

### 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:

| data | data frame or matrix containing the variables in the model. |
|---|---|
| missing.val | a number to replace missing values. |
| bic | Numeric value with the corresponding BIC. |
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| beta_estimate | posterior estimation of beta. |
| theta_estimate | posterior estimation of theta. |
| sigma_theta_estimate | |
| | posterior estimation of standard deviation of theta. |
| sigma_estimate | posterior estimation of standard deviation. |
| gamma_estimate | posterior estimation of gamma. |
| z_estimate | posterior estimation of z. |
| w_estimate | posterior estimation of w. |

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

## References

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

## Examples

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

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

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

lsirm_result <- lsirm1pl_normal_mar_ss(data)

# The code following can achieve the same result.
lsirm_result <- lsirm(data ~ lsirm1pl(spikenslab = TRUE, fixed_gamma = FALSE,
missing_data = 'mar', missing = 99))
```

---

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

---

### Description

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

### Usage

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

### Arguments

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

| | |
|---|---|
| nburn | Numeric; number of initial, pre-thinning, MCMC iterations to discard. default value is 2500. |
| nthin | Numeric;number of thinning, MCMC iterations to discard. default value is 5. |
| nprint | Numeric; MCMC samples is displayed during execution of MCMC chain for each nprint. default value is 500. |
| jump_beta | Numeric; jumping rule of the proposal density for beta. default value is 0.4. |
| jump_theta | Numeric; jumping rule of the proposal density for theta. default value is 1.0. |
| jump_gamma | Numeric; jumping rule of the proposal density for gamma. default value is 0.025. |
| jump_z | Numeric; jumping rule of the proposal density for z. default value is 0.5. |
| jump_w | Numeric; jumping rule of the proposal density for w. default value is 0.5. |
| pr_mean_beta | Numeric; mean of normal prior for beta. default value is 0. |
| pr_sd_beta | Numeric; standard deviation of normal prior for beta. default value is 1.0. |
| pr_mean_theta | Numeric; mean of normal prior for theta. default value is 0. |
| pr_mean_gamma | Numeric; mean of log normal prior for gamma. default value is 0.5. |
| pr_sd_gamma | Numeric; standard deviation of log normal prior for gamma. default value is 1.0. |
| pr_a_theta | Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001. |
| pr_b_theta | Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001. |
| pr_a_eps | Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001. |
| pr_b_eps | Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001. |
| missing.val | Numeric; a number to replace missing values. default value is 99. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

### 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:

| | |
|---|---|
| `data` | data frame or matrix containing the variables in the model. |
| `missing.val` | a number to replace missing values. |
| `bic` | Numeric value with the corresponding BIC. |
| `mcmc_inf` | number of mcmc iteration, burn-in periods, and thinning intervals. |
| `map_inf` | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| `beta_estimate` | posterior estimation of beta. |
| `theta_estimate` | posterior estimation of theta. |
| `sigma_theta_estimate` | |
| | posterior estimation of standard deviation of theta. |
| `sigma_estimate` | posterior estimation of standard deviation. |
| `gamma_estimate` | posterior estimation of gamma. |
| `z_estimate` | posterior estimation of z. |
| `w_estimate` | posterior estimation of w. |
| `beta` | posterior samples of beta. |
| `theta` | posterior samples of theta. |
| `theta_sd` | posterior samples of standard deviation of theta. |
| `sigma` | posterior samples of standard deviation. |
| `gamma` | posterior samples of gamma. |
| `z` | posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| `w` | posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| `accept_beta` | accept ratio of beta. |
| `accept_theta` | accept ratio of theta. |
| `accept_w` | accept ratio of w. |
| `accept_z` | accept ratio of z. |
| `accept_gamma` | accept ratio of gamma. |

**References**

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

## Examples

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

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

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

lsirm_result <- lsirm1pl_normal_mcar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm(data ~ lsirm1pl(spikenslab = FALSE, fixed_gamma = FALSE,
missing_data ='mcar', missing.val = 99))
```

---

lsirm1pl_normal_mcar_ss

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

---

## Description

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

## Usage

```
lsirm1pl_normal_mcar_ss(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_gamma = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
```

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

## Arguments

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

| | |
|---|---|
| pr_b_theta | Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001. |
| pr_a_eps | Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001. |
| pr_b_eps | Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001. |
| pr_xi_a | Numeric; first shape parameter of beta prior for latent variable xi. default value is 1. |
| pr_xi_b | Numeric; second shape parameter of beta prior for latent variable xi. default value is 1. |
| missing.val | Numeric; a number to replace missing values. default value is 99. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

## 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:

| | |
|---|---|
| data | data frame or matrix containing the variables in the model. |
| missing.val | a number to replace missing values. |
| bic | Numeric value with the corresponding BIC. |
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| beta_estimate | posterior estimation of beta. |
| theta_estimate | posterior estimation of theta. |
| sigma_theta_estimate | |
| | posterior estimation of standard deviation of theta. |
| sigma_estimate | posterior estimation of standard deviation. |
| gamma_estimate | posterior estimation of gamma. |
| z_estimate | posterior estimation of z. |

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

### References

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

### Examples

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

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

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

lsirm_result <- lsirm1pl_normal_mcar_ss(data)

# The code following can achieve the same result.
lsirm_result <- lsirm(data ~ lsirm1pl(spikenslab = TRUE, fixed_gamma = FALSE,
missing_data ='mcar', missing.val = 99))
```

---

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,
  verbose = FALSE
)
```

### 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. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

### Details

lsirm1pl_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

lsirm1pl_normal_o returns an object of list containing the following components:

| | |
|---|---|
| data | data frame or matrix containing the variables in the model. |
| bic | Numeric value with the corresponding BIC. |
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |

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

## Examples

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

lsirm_result <- lsirm1pl_normal_o(data)

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

---

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

---

## Description

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

## Usage

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

## Arguments

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

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

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

### Value

lsirm1pl_normal_ss returns an object of list containing the following components:

| data | data frame or matrix containing the variables in the model. |
|---|---|
| bic | Numeric value with the corresponding BIC. |
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| beta_estimate | posterior estimation of beta. |

theta_estimate  posterior estimation of theta.

sigma_theta_estimate

                 posterior estimation of standard deviation of theta.

sigma_estimate  posterior estimation of standard deviation.

gamma_estimate  posterior estimation of gamma.

z_estimate  posterior estimation of z.

w_estimate  posterior estimation of w.

pi_estimate  posterior estimation of phi. inclusion probability of gamma. if estimation of phi is less than 0.5, choose Rasch model with gamma = 0, otherwise latent space model with gamma > 0.

beta  posterior samples of beta.

theta  posterior samples of theta.

theta_sd  posterior samples of standard deviation of theta.

sigma  posterior samples of standard deviation.

gamma  posterior samples of gamma.

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

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

pi  posterior samples of phi which is indicator of spike and slab prior. If phi is 1, log gamma follows the slab prior, otherwise follows the spike prior.

accept_beta  accept ratio of beta.

accept_theta  accept ratio of theta.

accept_w  accept ratio of w.

accept_z  accept ratio of z.

accept_gamma  accept ratio of gamma.

### References

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

### Examples

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

lsirm_result <- lsirm1pl_normal_ss(data)

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

---

lsirm1pl_o                          *1pl LSIRM model.*

---

### Description

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

### Usage

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

### 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. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

## 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:

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

## Value

lsirm1pl_o returns an object of list containing the following components:

| | |
|---|---|
| data | data frame or matrix containing the variables in the model. |
| bic | Numeric value with the corresponding BIC. |
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| 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 <- lsirm(data ~ lsirm1pl(spikenslab = FALSE, fixed_gamma = FALSE))
```

---

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

---

## Description

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

## Usage

```
lsirm1pl_ss(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
```

```
    jump_beta = 0.4,
    jump_theta = 1,
    jump_gamma = 1,
    jump_z = 0.5,
    jump_w = 0.5,
    pr_mean_beta = 0,
    pr_sd_beta = 1,
    pr_mean_theta = 0,
    pr_spike_mean = -3,
    pr_spike_sd = 1,
    pr_slab_mean = 0.5,
    pr_slab_sd = 1,
    pr_a_theta = 0.001,
    pr_b_theta = 0.001,
    pr_xi_a = 1,
    pr_xi_b = 1,
    verbose = FALSE
)
```

## 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. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

### 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:

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

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:

| data | data frame or matrix containing the variables in the model. |
|---|---|
| bic | Numeric value with the corresponding BIC. |
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| beta_estimate | posterior estimation of beta. |
| theta_estimate | posterior estimation of theta. |
| sigma_theta_estimate | |
| | posterior estimation of standard deviation of theta. |
| gamma_estimate | posterior estimation of gamma. |
| z_estimate | posterior estimation of z. |
| w_estimate | posterior estimation of w. |
| pi_estimate | posterior estimation of phi. inclusion probability of gamma. if estimation of phi is less than 0.5, choose Rasch model with gamma = 0, otherwise latent space model with gamma > 0. |
| beta | posterior samples of beta. |
| theta | posterior samples of theta. |
| theta_sd | posterior samples of standard deviation of theta. |

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

### References

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

### Examples

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

lsirm_result <- lsirm1pl_ss(data)

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

---

lsirm2pl                     *Fit a 2pl LSIRM model*

---

### Description

lsirm2pl integrates all functions related to 2pl LSIRM

### Usage

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

## Arguments

| | |
|---|---|
| `data` | Matrix; binary or 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. |
| `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_normal_o](),
[lsirm2pl_normal_fixed_gamma](), [lsirm2pl_normal_mar](), [lsirm2pl_mcar](),[lsirm2pl_normal_fixed_gamma_mar](),
[lsirm2pl_normal_fixed_gamma_mcar](), [lsirm2pl_normal_ss](), [lsirm2pl_normal_mar_ss](), [lsirm2pl_normal_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,
    verbose = FALSE
)
```

## 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. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

**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:

| | |
|---|---|
| data | data frame or matrix containing the variables in the model. |
| bic | Numeric value with the corresponding BIC. |
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| beta_estimate | posterior estimation of beta. |
| theta_estimate | posterior estimation of theta. |
| sigma_theta_estimate | |
| | posterior estimation of standard deviation of theta. |
| alpha_estimate | posterior estimation of alpha. |
| z_estimate | posterior estimation of z. |
| w_estimate | posterior estimation of w. |
| beta | posterior samples of beta. |
| theta | posterior samples of theta. |
| theta_sd | posterior samples of standard deviation of theta. |
| alpha | posterior samples of alpha. |
| z | posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| w | posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| accept_beta | accept ratio of beta. |
| accept_theta | accept ratio of theta. |
| accept_w | accept ratio of w. |
| accept_z | accept ratio of z. |
| accept_alpha | accept ratio of alpha. |

## Examples

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

lsirm_result <- lsirm2pl_fixed_gamma(data)

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

---

lsirm2pl_fixed_gamma_mar

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

---

## Description

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

## Usage

```
lsirm2pl_fixed_gamma_mar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  missing.val = 99,
```

```
    verbose = FALSE
)
```

## 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.val | Numeric; a number to replace missing values. default value is 99. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

## 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 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 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:

| | |
|---|---|
| `data` | data frame or matrix containing the variables in the model. |
| `missing.val` | a number to replace missing values. |
| `bic` | Numeric value with the corresponding BIC. |
| `mcmc_inf` | number of mcmc iteration, burn-in periods, and thinning intervals. |
| `map_inf` | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| `beta_estimate` | posterior estimation of beta. |
| `theta_estimate` | posterior estimation of theta. |
| `sigma_theta_estimate` | |
| | posterior estimation of standard deviation of theta. |
| `alpha_estimate` | posterior estimation of alpha. |
| `z_estimate` | posterior estimation of z. |
| `w_estimate` | posterior estimation of w. |
| `imp_estimate` | probability of imputating a missing value with 1. |
| `beta` | posterior samples of beta. |
| `theta` | posterior samples of theta. |
| `theta_sd` | posterior samples of standard deviation of theta. |
| `alpha` | posterior samples of alpha. |
| `z` | posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| `w` | posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| `imp` | imputation for missing Values using posterior samples. |
| `accept_beta` | accept ratio of beta. |
| `accept_theta` | accept ratio of theta. |
| `accept_w` | accept ratio of w. |
| `accept_z` | accept ratio of z. |
| `accept_alpha` | accept ratio of alpha. |

**References**

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

## Examples

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

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

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

lsirm_result <- lsirm2pl_fixed_gamma_mar(data)

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

---

lsirm2pl_fixed_gamma_mcar

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

---

## Description

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

## Usage

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

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

## 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.val | Numeric; a number to replace missing values. default value is 99. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

## 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 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:

| | |
|---|---|
| `data` | data frame or matrix containing the variables in the model. |
| `missing.val` | a number to replace missing values. |
| `bic` | Numeric value with the corresponding BIC. |
| `mcmc_inf` | number of mcmc iteration, burn-in periods, and thinning intervals. |
| `map_inf` | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| `beta_estimate` | posterior estimation of beta. |
| `theta_estimate` | posterior estimation of theta. |
| `sigma_theta_estimate` | |
| | posterior estimation of standard deviation of theta. |
| `alpha_estimate` | posterior estimation of alpha. |
| `z_estimate` | posterior estimation of z. |
| `w_estimate` | posterior estimation of w. |
| `beta` | posterior samples of beta. |
| `theta` | posterior samples of theta. |
| `theta_sd` | posterior samples of standard deviation of theta. |
| `alpha` | posterior samples of alpha. |
| `z` | posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| `w` | posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| `accept_beta` | accept ratio of beta. |
| `accept_theta` | accept ratio of theta. |
| `accept_w` | accept ratio of w. |
| `accept_z` | accept ratio of z. |
| `accept_alpha` | accept ratio of alpha. |

### References

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

### Examples

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

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

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

lsirm_result <- lsirm2pl_fixed_gamma_mcar(data)

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

---

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

---

### Description

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

### Usage

```
lsirm2pl_mar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_gamma = 0.025,
```

```
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_gamma = 0.5,
  pr_sd_gamma = 1,
  pr_mean_alpha = 0.5,
  pr_sd_alpha = 1,
  pr_a_theta = 0.001,
  pr_b_theta = 0.001,
  missing.val = 99,
  verbose = FALSE
)
```

## 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.val | Numeric; a number to replace missing values. default value is 99. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

### 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 the item effect is assumed to have additional discrimination parameter $\alpha_i$ multiplied by $\theta_j$:

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

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:

| | |
|---|---|
| data | data frame or matrix containing the variables in the model. |
| missing.val | a number to replace missing values. |
| bic | Numeric value with the corresponding BIC. |
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| beta_estimate | posterior estimation of beta. |
| theta_estimate | posterior estimation of theta. |
| sigma_theta_estimate | |
| | posterior estimation of standard deviation of theta. |
| gamma_estimate | posterior estimation of gamma. |
| alpha_estimate | posterior estimation of alpha. |
| z_estimate | posterior estimation of z. |
| w_estimate | posterior estimation of w. |
| imp_estimate | |
| beta | posterior samples of beta. |
| theta | posterior samples of theta. |
| theta_sd | posterior samples of standard deviation of theta. |
| gamma | posterior samples of gamma. |

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

### References

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

### Examples

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

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

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

lsirm_result <- lsirm2pl_mar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm(data ~ lsirm2pl(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.val = 99,
  verbose = FALSE
)
```

**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.val | Numeric; a number to replace missing values. default value is 99. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

### 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 the item effect is assumed to have additional discrimination parameter $\alpha_i$ multiplied by $\theta_j$:

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

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

## Value

lsirm2pl_mar_ss returns an object of list containing the following components:

| | |
|---|---|
| data | data frame or matrix containing the variables in the model. |
| missing.val | a number to replace missing values. |
| bic | Numeric value with the corresponding BIC. |
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| beta_estimate | posterior estimation of beta. |
| theta_estimate | posterior estimation of theta. |
| sigma_theta_estimate | |
| | posterior estimation of standard deviation of theta. |
| gamma_estimate | posterior estimation of gamma. |
| alpha_estimate | posterior estimation of alpha. |
| z_estimate | posterior estimation of z. |
| w_estimate | posterior estimation of w. |
| imp_estimate | |
| pi_estimate | posterior estimation of phi. inclusion probability of gamma. if estimation of phi is less than 0.5, choose Rasch model with gamma = 0, otherwise latent space model with gamma > 0. |
| beta | posterior samples of beta. |
| theta | posterior samples of theta. |
| theta_sd | posterior samples of standard deviation of theta. |
| gamma | posterior samples of gamma. |
| alpha | posterior samples of alpha. |
| z | posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| w | posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| imp | |
| pi | posterior samples of phi which is indicator of spike and slab prior. If phi is 1, log gamma follows the slab prior, otherwise follows the spike prior. |
| accept_beta | accept ratio of beta. |
| accept_theta | accept ratio of theta. |
| accept_w | accept ratio of w. |
| accept_z | accept ratio of z. |
| accept_gamma | accept ratio of gamma. |
| accept_alpha | accept ratio of alpha. |

## References

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

## Examples

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

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

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

lsirm_result <- lsirm2pl_mar_ss(data)

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

---

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

---

## Description

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

## Usage

```
lsirm2pl_mcar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
```

```
    jump_alpha = 1,
    jump_gamma = 0.025,
    jump_z = 0.5,
    jump_w = 0.5,
    pr_mean_beta = 0,
    pr_sd_beta = 1,
    pr_mean_theta = 0,
    pr_mean_gamma = 0.5,
    pr_sd_gamma = 1,
    pr_mean_alpha = 0.5,
    pr_sd_alpha = 1,
    pr_a_theta = 0.001,
    pr_b_theta = 0.001,
    missing.val = 99,
    verbose = FALSE
)
```

## 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.val | Numeric; a number to replace missing values. default value is 99. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

### 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 the item effect is assumed to have additional discrimination parameter $\alpha_i$ multiplied by $\theta_j$:

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

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

### Value

lsirm2pl_mar returns an object of list containing the following components:

| | |
|---|---|
| data | data frame or matrix containing the variables in the model. |
| missing.val | a number to replace missing values. |
| bic | Numeric value with the corresponding BIC. |
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| beta_estimate | posterior estimation of beta. |
| theta_estimate | posterior estimation of theta. |
| sigma_theta_estimate | |
| | posterior estimation of standard deviation of theta. |
| gamma_estimate | posterior estimation of gamma. |
| alpha_estimate | posterior estimation of alpha. |
| z_estimate | posterior estimation of z. |
| w_estimate | posterior estimation of w. |
| beta | posterior samples of beta. |
| theta | posterior samples of theta. |
| theta_sd | posterior samples of standard deviation of theta. |
| gamma | posterior samples of gamma. |

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

### References

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

### Examples

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

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

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

lsirm_result <- lsirm2pl_mcar(data)

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

---

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

---

### Description

lsirm2pl_mar_ss is used to fit 2pl LSIRM model based on spike-and-slab priors in incomplete data assumed to be missing completely at random. lsirm2pl_mar_ss factorizes item response matrix into column-wise item effect, row-wise respondent effect in a latent space, while ignoring the missing

element under the assumption of missing completely at random. Unlike 1pl model, 2pl model assumes the item effect can vary according to respondent, allowing additional parameter multiplied with respondent effect. The resulting latent space provides an interaction map that represents interactions between respondents and items.

## Usage

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

## 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.val | Numeric; a number to replace missing values. default value is 99. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

### 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 $\theta_j$:

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

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

**Value**

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

| | |
|---|---|
| `data` | data frame or matrix containing the variables in the model. |
| `missing.val` | a number to replace missing values. |
| `bic` | Numeric value with the corresponding BIC. |
| `mcmc_inf` | number of mcmc iteration, burn-in periods, and thinning intervals. |
| `map_inf` | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| `beta_estimate` | posterior estimation of beta. |
| `theta_estimate` | posterior estimation of theta. |
| `sigma_theta_estimate` | |
| | posterior estimation of standard deviation of theta. |
| `gamma_estimate` | posterior estimation of gamma. |
| `alpha_estimate` | posterior estimation of alpha. |
| `z_estimate` | posterior estimation of z. |
| `w_estimate` | posterior estimation of w. |
| `pi_estimate` | posterior estimation of phi. inclusion probability of gamma. if estimation of phi is less than 0.5, choose Rasch model with gamma = 0, otherwise latent space model with gamma > 0. |
| `beta` | posterior samples of beta. |
| `theta` | posterior samples of theta. |
| `theta_sd` | posterior samples of standard deviation of theta. |
| `gamma` | posterior samples of gamma. |
| `alpha` | posterior samples of alpha. |
| `z` | posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| `w` | posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| `pi` | posterior samples of phi which is indicator of spike and slab prior. If phi is 1, log gamma follows the slab prior, otherwise follows the spike prior. |
| `accept_beta` | accept ratio of beta. |
| `accept_theta` | accept ratio of theta. |
| `accept_w` | accept ratio of w. |
| `accept_z` | accept ratio of z. |
| `accept_gamma` | accept ratio of gamma. |
| `accept_alpha` | accept ratio of alpha. |

**References**

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

## Examples

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

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

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

lsirm_result <- lsirm2pl_mcar_ss(data)

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

---

lsirm2pl_normal            *2pl LSIRM model with normal likelihood*

---

### Description

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

### Usage

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

### Arguments

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

### Value

lsirm2pl_normal returns an object of list. See corresponding function.

**Note**

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

**See Also**

[lsirm2pl_normal_o](#), [lsirm2pl_normal_fixed_gamma](#), [lsirm2pl_normal_mar](#),
[lsirm2pl_normal_mcar](#),[lsirm2pl_normal_fixed_gamma_mar](#), [lsirm2pl_normal_fixed_gamma_mcar](#),
[lsirm2pl_normal_ss](#), [lsirm2pl_normal_mar_ss](#), [lsirm2pl_normal_mcar_ss](#)

---

lsirm2pl_normal_fixed_gamma

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

---

**Description**

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

**Usage**

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

```
    verbose = FALSE
  )
```

## Arguments

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

## Details

`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 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:

| | |
|---|---|
| `data` | data frame or matrix containing the variables in the model. |
| `bic` | Numeric value with the corresponding BIC. |
| `mcmc_inf` | number of mcmc iteration, burn-in periods, and thinning intervals. |
| `map_inf` | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| `beta_estimate` | posterior estimation of beta. |
| `theta_estimate` | posterior estimation of theta. |
| `sigma_theta_estimate` | |
| | posterior estimation of standard deviation of theta. |
| `sigma_estimate` | posterior estimation of standard deviation. |
| `alpha_estimate` | posterior estimation of alpha. |
| `z_estimate` | posterior estimation of z. |
| `w_estimate` | posterior estimation of w. |
| `beta` | posterior samples of beta. |
| `theta` | posterior samples of theta. |
| `theta_sd` | posterior samples of standard deviation of theta. |
| `sigma` | posterior samples of standard deviation. |
| `alpha` | posterior samples of alpha. |
| `z` | posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| `w` | posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| `accept_beta` | accept ratio of beta. |
| `accept_theta` | accept ratio of theta. |
| `accept_w` | accept ratio of w. |
| `accept_z` | accept ratio of z. |
| `accept_alpha` | accept ratio of alpha. |

## Examples

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

lsrm_result <- lsirm2pl_normal_fixed_gamma(data)

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

lsirm2pl_normal_fixed_gamma_mar

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

### Description

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

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

### Usage

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

### 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. |
| pr_mean_theta | Numeric; mean of normal prior for theta. default value is 0. |
| pr_mean_alpha | Numeric; mean of normal prior for alpha. default value is 0.5. |
| pr_sd_alpha  | Numeric; mean of normal prior for beta. default value is 1.0. |
| pr_a_theta   | Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001. |
| pr_b_theta   | Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001. |
| pr_a_eps     | Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001. |
| pr_b_eps     | Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001. |
| missing.val  | Numeric; a number to replace missing values. default value is 99. |
| verbose      | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

### 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 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:

| | |
|---|---|
| `data` | data frame or matrix containing the variables in the model. |
| `missing.val` | a number to replace missing values. |
| `bic` | Numeric value with the corresponding BIC. |
| `mcmc_inf` | number of mcmc iteration, burn-in periods, and thinning intervals. |
| `map_inf` | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| `beta_estimate` | posterior estimation of beta. |
| `theta_estimate` | posterior estimation of theta. |
| `sigma_theta_estimate` | |
| | posterior estimation of standard deviation of theta. |
| `sigma_estimate` | posterior estimation of standard deviation. |
| `alpha_estimate` | posterior estimation of alpha. |
| `z_estimate` | posterior estimation of z. |
| `w_estimate` | posterior estimation of w. |
| `imp_estimate` | |
| `beta` | posterior samples of beta. |
| `theta` | posterior samples of theta. |
| `theta_sd` | posterior samples of standard deviation of theta. |
| `sigma` | posterior samples of standard deviation. |
| `alpha` | posterior samples of alpha. |
| `z` | posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| `w` | posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| `imp` | |
| `accept_beta` | accept ratio of beta. |
| `accept_theta` | accept ratio of theta. |
| `accept_w` | accept ratio of w. |
| `accept_z` | accept ratio of z. |
| `accept_alpha` | accept ratio of alpha. |

## Examples

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

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

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

lsirm_result <- lsirm2pl_normal_fixed_gamma_mar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm(data ~ lsirm2pl(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.val = 99,
    verbose = FALSE
)
```

## Arguments

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

| | |
|---|---|
| missing.val | Numeric; a number to replace missing values. default value is 99. |
| verbose | Logical; If TRUE, MCMC samples are printed for each `nprint`. default value is FALSE |

### 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 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:

| | |
|---|---|
| data | data frame or matrix containing the variables in the model. |
| missing.val | a number to replace missing values. |
| bic | Numeric value with the corresponding BIC. |
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| beta_estimate | posterior estimation of beta. |
| theta_estimate | posterior estimation of theta. |
| sigma_theta_estimate | |
| | posterior estimation of standard deviation of theta. |
| sigma_estimate | posterior estimation of standard deviation. |
| alpha_estimate | posterior estimation of alpha. |
| z_estimate | posterior estimation of z. |
| w_estimate | posterior estimation of w. |
| beta | posterior samples of beta. |
| theta | posterior samples of theta. |
| theta_sd | posterior samples of standard deviation of theta. |
| sigma | posterior samples of standard deviation. |
| alpha | posterior samples of alpha. |
| z | posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |

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

## Examples

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

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

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

lsirm_result <- lsirm2pl_normal_fixed_gamma_mcar(data)

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

---

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

---

## Description

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

## Usage

```
lsirm2pl_normal_mar(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
```

```
    nprint = 500,
    jump_beta = 0.4,
    jump_theta = 1,
    jump_alpha = 1,
    jump_gamma = 1,
    jump_z = 0.5,
    jump_w = 0.5,
    pr_mean_beta = 0,
    pr_sd_beta = 1,
    pr_mean_theta = 0,
    pr_mean_gamma = 0.5,
    pr_sd_gamma = 1,
    pr_mean_alpha = 0.5,
    pr_sd_alpha = 1,
    pr_a_theta = 0.001,
    pr_b_theta = 0.001,
    pr_a_eps = 0.001,
    pr_b_eps = 0.001,
    missing.val = 99,
    verbose = FALSE
)
```

## Arguments

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

| pr_mean_gamma | Numeric; mean of log normal prior for gamma. default value is 0.5. |
| pr_sd_gamma | Numeric; standard deviation of log normal prior for gamma. default value is 1.0. |
| pr_mean_alpha | Numeric; mean of normal prior for alpha. default value is 0.5. |
| pr_sd_alpha | Numeric; mean of normal prior for beta. default value is 1.0. |
| pr_a_theta | Numeric; shape parameter of inverse gamma prior for variance of theta. default value is 0.001. |
| pr_b_theta | Numeric; scale parameter of inverse gamma prior for variance of theta. default value is 0.001. |
| pr_a_eps | Numeric; shape parameter of inverse gamma prior for variance of data likelihood. default value is 0.001. |
| pr_b_eps | Numeric; scale parameter of inverse gamma prior for variance of data likelihood default value is 0.001. |
| missing.val | Numeric; a number to replace missing values. default value is 99. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

## 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:

| data | data frame or matrix containing the variables in the model. |
| missing.val | a number to replace missing values. |
| bic | Numeric value with the corresponding BIC. |
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| beta_estimate | posterior estimation of beta. |
| theta_estimate | posterior estimation of theta. |
| sigma_theta_estimate | |
| | posterior estimation of standard deviation of theta. |
| sigma_estimate | posterior estimation of standard deviation. |

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

### References

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

### Examples

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

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

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

lsirm_result <- lsirm2pl_normal_mar(data)

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

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

### Description

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

### Usage

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

```
    verbose = FALSE
)
```

## 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.val | Numeric; a number to replace missing values. default value is 99. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

## 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:

| | |
|---|---|
| data | data frame or matrix containing the variables in the model. |
| missing.val | a number to replace missing values. |
| bic | Numeric value with the corresponding BIC. |
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| beta_estimate | posterior estimation of beta. |
| theta_estimate | posterior estimation of theta. |
| sigma_theta_estimate | |
| | posterior estimation of standard deviation of theta. |
| sigma_estimate | posterior estimation of standard deviation. |
| gamma_estimate | posterior estimation of gamma. |
| alpha_estimate | posterior estimation of alpha. |
| z_estimate | posterior estimation of z. |
| w_estimate | posterior estimation of w. |
| pi_estimate | posterior estimation of phi. inclusion probability of gamma. if estimation of phi is less than 0.5, choose Rasch model with gamma = 0, otherwise latent space model with gamma > 0. |
| imp_estimate | estimation of imputing missing values. |
| beta | posterior samples of beta. |

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

### References

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

### Examples

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

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

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

lsirm_result <- lsirm2pl_normal_mar_ss(data)

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

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

### Description

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

### Usage

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

### 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.                                                         |
| 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.val  | Numeric; a number to replace missing values. default value is 99.                                                                        |
| verbose      | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE                                                       |

### 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:

| | |
|---|---|
| data | data frame or matrix containing the variables in the model. |
| missing.val | a number to replace missing values. |
| bic | Numeric value with the corresponding BIC. |
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| beta_estimate | posterior estimation of beta. |
| theta_estimate | posterior estimation of theta. |
| sigma_theta_estimate | |
| | posterior estimation of standard deviation of theta. |
| sigma_estimate | posterior estimation of standard deviation. |
| gamma_estimate | posterior estimation of gamma. |
| alpha_estimate | posterior estimation of alpha. |
| z_estimate | posterior estimation of z. |
| w_estimate | posterior estimation of w. |
| beta | posterior samples of beta. |
| theta | posterior samples of theta. |
| theta_sd | posterior samples of standard deviation of theta. |
| sigma | posterior samples of standard deviation. |
| gamma | posterior samples of gamma. |
| alpha | posterior samples of alpha. |
| z | posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| w | posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| accept_beta | accept ratio of beta. |
| accept_theta | accept ratio of theta. |
| accept_w | accept ratio of w. |
| accept_z | accept ratio of z. |
| accept_gamma | accept ratio of gamma. |
| accept_alpha | accept ratio of alpha. |

#### References

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

#### Examples

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

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

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

lsirm_result <- lsirm2pl_normal_mcar(data)

# The code following can achieve the same result.
lsirm_result <- lsirm(data ~ lsirm2pl(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.val = 99,
    verbose = FALSE
)
```

## 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.val | Numeric; a number to replace missing values. default value is 99. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

## 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 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:

| | |
|---|---|
| data | data frame or matrix containing the variables in the model. |
| missing.val | a number to replace missing values. |
| bic | Numeric value with the corresponding BIC. |

| | |
|---|---|
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| beta_estimate | posterior estimation of beta. |
| theta_estimate | posterior estimation of theta. |
| sigma_theta_estimate | |
| | posterior estimation of standard deviation of theta. |
| sigma_estimate | posterior estimation of standard deviation. |
| gamma_estimate | posterior estimation of gamma. |
| alpha_estimate | posterior estimation of alpha. |
| z_estimate | posterior estimation of z. |
| w_estimate | posterior estimation of w. |
| pi_estimate | posterior estimation of phi. inclusion probability of gamma. if estimation of phi is less than 0.5, choose Rasch model with gamma = 0, otherwise latent space model with gamma > 0. |
| beta | posterior samples of beta. |
| theta | posterior samples of theta. |
| theta_sd | posterior samples of standard deviation of theta. |
| sigma | posterior samples of standard deviation. |
| gamma | posterior samples of gamma. |
| alpha | posterior samples of alpha. |
| z | posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| w | posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| pi | posterior samples of phi which is indicator of spike and slab prior. If phi is 1, log gamma follows the slab prior, otherwise follows the spike prior. |
| accept_beta | accept ratio of beta. |
| accept_theta | accept ratio of theta. |
| accept_w | accept ratio of w. |
| accept_z | accept ratio of z. |
| accept_gamma | accept ratio of gamma. |
| accept_alpha | accept ratio of alpha. |

### References

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

**Examples**

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

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

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

lsirm_result <- lsirm2pl_normal_mcar_ss(data)

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

---

lsirm2pl_normal_o              *2pl LSIRM model with normal likelihood*

---

**Description**

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

**Usage**

```
lsirm2pl_normal_o(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_gamma = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
  pr_sd_beta = 1,
  pr_mean_theta = 0,
  pr_mean_gamma = 0.5,
```

```
    pr_sd_gamma = 1,
    pr_mean_alpha = 0.5,
    pr_sd_alpha = 1,
    pr_a_theta = 0.001,
    pr_b_theta = 0.001,
    pr_a_eps = 0.001,
    pr_b_eps = 0.001,
    verbose = FALSE
)
```

## 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. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

### 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:

| | |
|---|---|
| data | data frame or matrix containing the variables in the model. |
| bic | Numeric value with the corresponding BIC. |
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| beta_estimate | posterior estimation of beta. |
| theta_estimate | posterior estimation of theta. |
| sigma_theta_estimate | |
| | posterior estimation of standard deviation of theta. |
| sigma_estimate | posterior estimation of standard deviation. |
| gamma_estimate | posterior estimation of gamma. |
| alpha_estimate | posterior estimation of alpha. |
| z_estimate | posterior estimation of z. |
| w_estimate | posterior estimation of w. |
| beta | posterior samples of beta. |
| theta | posterior samples of theta. |
| theta_sd | posterior samples of standard deviation of theta. |
| sigma | posterior samples of standard deviation. |
| gamma | posterior samples of gamma. |
| alpha | posterior samples of alpha. |
| z | posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| w | posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |

| | |
|---|---|
| accept_beta | accept ratio of beta. |
| accept_theta | accept ratio of theta. |
| accept_w | accept ratio of w. |
| accept_z | accept ratio of z. |
| accept_gamma | accept ratio of gamma. |
| accept_alpha | accept ratio of alpha. |

### Examples

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

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

---

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

---

### Description

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

### Usage

```
lsirm2pl_normal_ss(
  data,
  ndim = 2,
  niter = 15000,
  nburn = 2500,
  nthin = 5,
  nprint = 500,
  jump_beta = 0.4,
  jump_theta = 1,
  jump_alpha = 1,
  jump_gamma = 1,
  jump_z = 0.5,
  jump_w = 0.5,
  pr_mean_beta = 0,
```

```
    pr_sd_beta = 1,
    pr_mean_theta = 0,
    pr_spike_mean = -3,
    pr_spike_sd = 1,
    pr_slab_mean = 0.5,
    pr_slab_sd = 1,
    pr_mean_alpha = 0.5,
    pr_sd_alpha = 1,
    pr_a_eps = 0.001,
    pr_b_eps = 0.001,
    pr_a_theta = 0.001,
    pr_b_theta = 0.001,
    pr_xi_a = 0.001,
    pr_xi_b = 0.001,
    verbose = FALSE
)
```

## 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. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

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

### Value

lsirm2pl_normal_ss returns an object of list containing the following components:

| | |
|---|---|
| data | data frame or matrix containing the variables in the model. |
| bic | Numeric value with the corresponding BIC. |
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| beta_estimate | posterior estimation of beta. |
| theta_estimate | posterior estimation of theta. |
| sigma_theta_estimate | |
| | posterior estimation of standard deviation of theta. |
| sigma_estimate | posterior estimation of standard deviation. |
| gamma_estimate | posterior estimation of gamma. |
| alpha_estimate | posterior estimation of alpha. |

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

### References

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

### Examples

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

lsirm_result <- lsirm2pl_normal_ss(data)

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

---

lsirm2pl_o                    *2pl LSIRM model*

---

### Description

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

### Usage

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

### 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. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

### 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 $\theta_j$:

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

### Value

lsirm2pl_o returns an object of list containing the following components:

| | |
|---|---|
| data | data frame or matrix containing the variables in the model. |
| bic | Numeric value with the corresponding BIC. |
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |

| | |
|---|---|
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| 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 <- lsirm(data ~ lsirm2pl(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,
  verbose = FALSE
)
```

**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_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. |
| verbose | Logical; If TRUE, MCMC samples are printed for each nprint. default value is FALSE |

### 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 $\theta_j$:

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

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:

| | |
|---|---|
| data | data frame or matrix containing the variables in the model. |
| bic | Numeric value with the corresponding BIC. |
| mcmc_inf | number of mcmc iteration, burn-in periods, and thinning intervals. |
| map_inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| beta_estimate | posterior estimation of beta. |
| theta_estimate | posterior estimation of theta. |
| sigma_theta_estimate | |
| | posterior estimation of standard deviation of theta. |
| gamma_estimate | posterior estimation of gamma. |
| alpha_estimate | posterior estimation of alpha. |
| z_estimate | posterior estimation of z. |
| w_estimate | posterior estimation of w. |
| pi_estimate | posterior estimation of phi. inclusion probability of gamma. if estimation of phi is less than 0.5, choose Rasch model with gamma = 0, otherwise latent space model with gamma > 0. |
| beta | posterior samples of beta. |
| theta | posterior samples of theta. |
| theta_sd | posterior samples of standard deviation of theta. |
| gamma | posterior samples of gamma. |
| alpha | posterior samples of alpha. |
| z | posterior samples of z. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| w | posterior samples of w. The output is 3-dimensional matrix with last axis represent the dimension of latent space. |
| pi | posterior samples of phi which is indicator of spike and slab prior. If phi is 1, log gamma follows the slab prior, otherwise follows the spike prior. |
| accept_beta | accept ratio of beta. |
| accept_theta | accept ratio of theta. |
| accept_w | accept ratio of w. |
| accept_z | accept ratio of z. |
| accept_gamma | accept ratio of gamma. |
| accept_alpha | accept ratio of alpha. |

**References**

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

## Examples

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

lsirm_result <- lsirm2pl_ss(data)

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

---

onepl                    *1pl Rasch model.*

---

### Description

onepl is used to fit 1pl Rasch model.

### Usage

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

### Arguments

data        Matrix; binary item response matrix to be analyzed. Each row is assumed to be
            respondent and its column values are assumed to be response to the correspond-
            ing 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 $\theta_j$:

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

### Value

onepl returns an object of list containing the following components:

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

### Examples

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

result <- onepl(data)
```

---

plot.lsirm                    *Plotting the interaction map of fitted LSIRM model*

---

**Description**

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

**Usage**

```
## S3 method for class 'lsirm'
plot(
  x,
  option = "interaction",
  rotation = FALSE,
  cluster = NA,
  interact = FALSE,
  ...
)
```

**Arguments**

| | |
|---|---|
| x | object of class lsirm1pl, lsirm2pl. |
| option | character; If value is "interaction", draw the interaction map that represents interactions between respondents and items. If value is "beta", draw the boxplot for the posterior samples of beta. If value is "theta", draw the distribution of the theta estimates per total test score for the data. If value is "alpha", draw the boxplot for the posterior samples of alpha. The "alpha" is only available for 2pl LSIRM. |
| rotation | Logical; If TRUE the latent positions are visualized after oblique (oblimin) rotation. |
| cluster | Logical; If TRUE the cluster result are visualized by Point Process Cluster Analysis. |
| interact | Logical; If TRUE, draw the interaction map interactively. |
| ... | Additional arguments for the corresponding function. |

**Value**

plot returns the interaction map or boxplot for parameter estimate.

**Examples**

```
# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5),ncol=10,nrow=50)
lsirm_result <- lsirm(data ~ lsirm1pl(spikenslab = FALSE, fixed_gamma = FALSE))
```

```
plot(lsirm_result)

# use oblique rotation
plot(lsirm_result, rotation = TRUE)

# plotly
plot(lsirm_result, interact = TRUE)

# clustering
plot(lsirm_result, cluster = TRUE)
```

---

print.summary.lsirm        *Summary the result of LSIRM model*

---

### Description

summary is used to summary the result of LSIRM model.

summary.lsirm is used to summary the result of LSIRM model.

### Usage

```
## S3 method for class 'summary.lsirm'
print(x, ...)

## S3 method for class 'summary.lsirm'
print(x, ...)
```

### Arguments

| | |
|---|---|
| x | object of class lsirm1pl, lsirm2pl. |
| ... | Additional arguments. |

### Value

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

summary.lsirm contains following elements. A print method is available.

| | |
|---|---|
| call | R call used to fit the model. |
| coef | Covariate coefficients posterior means. |
| mcmc.opt | The number of mcmc iteration, burn-in periods, and thinning intervals. |
| map.inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |
| BIC | Numeric value with the corresponding BIC. |

| method | 1pl LSIRM or 2pl LSIRM |
|--------|------------------------|
| missing | The assumed missing type. One of NA, "mar" and "mcar". Default uses NA. |
| dtype | Binary or Continuous |
| ss | TRUE if using spike-slab prior |

## Examples

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


# generate example item response matrix
data     <- matrix(rbinom(500, size = 1, prob = 0.5),ncol=10,nrow=50)
lsirm_result <- lsirm(data ~ lsirm1pl())
summary(lsirm_result)
```

---

summary.lsirm            *Summary the result of LSIRM model*

---

## Description

summary is used to summary the result of LSIRM model.

## Usage

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

## Arguments

| object | object of class lsirm. |
|--------|------------------------|
| ... | Additional arguments. |

## Value

summary.lsirm contains following elements. A print method is available.

| call | R call used to fit the model. |
|------|-------------------------------|
| coef | Covariate coefficients posterior means. |
| mcmc.opt | The number of mcmc iteration, burn-in periods, and thinning intervals. |
| map.inf | value of log maximum a posterior and iteration number which have log maximum a posterior. |

| BIC | Numeric value with the corresponding BIC. |
|---|---|
| method | 1pl LSIRM or 2pl LSIRM |
| missing | The assumed missing type. One of NA, "mar" and "mcar". Default uses NA. |
| dtype | Type of input data(Binary or Continuous). |
| ss | TRUE if using spike-slab prior |

### Examples

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

# 1PL LSIRM object
lsirm_result <- lsirm(data ~ lsirm1pl())
summary(lsirm_result)
```

---

TDRI                        *Inductive Reasoning Developmental Test*

---

### Description

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

### Usage

```
data(TDRI)
```

### Format

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

### Details

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

### Source

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

---

| twopl | *2pl Rasch model.* |
|-------|---------------------|

---

### Description

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

### Usage

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

### Arguments

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

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

### Details

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

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

### Value

twopl returns an object of list containing the following components:

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

### Examples

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

result <- twopl(data)
```

# Index