Package 'fourPNO'

April 26, 2017

Type Package

Title Bayesian 4 Parameter Item Response Model

Version 1.0.4

Date 2017-04-26

Description Estimate Barton & Lord's (1981) <doi:10.1002/j.2333-8504.1981.tb01255.x> four parameter IRT model with lower and upper asymptotes using Bayesian formulation described by Culpepper (2016) <doi:10.1007/s11336-015-9477-6>.

URL https://github.com/tmsalab/fourPNO

BugReports https://github.com/tmsalab/fourPNO/issues

License GPL (>= 2)

Imports Rcpp (>= 0.12.10)

LinkingTo Rcpp (>= 0.12.10), RcppArmadillo (>= 0.7.800)

Depends R (>= 3.0.2)

RoxygenNote 6.0.1

NeedsCompilation yes

Author Steven Andrew Culpepper [aut, cre]

Maintainer Steven Andrew Culpepper <sculpepp@illinois.edu>

Repository CRAN

Date/Publication 2017-04-26 16:26:44 UTC

R topics documented:

`fourPNO-package` *fourPNO: Bayesian 4 Parameter Item Response Model*

Description

Estimate Barton & Lord's (1981) <doi:10.1002/j.2333-8504.1981.tb01255.x> four parameter IRT model with lower and upper asymptotes using Bayesian formulation described by Culpepper (2016) <doi:10.1007/s11336-015-9477-6>.

Author(s)

Maintainer: Steven Andrew Culpepper <sculpepp@illinois.edu>

See Also

Useful links:

- https://github.com/tmsalab/fourPNO
- Report bugs at https://github.com/tmsalab/fourPNO/issues

`Gibbs_2PNO` *Gibbs Implementation of 2PNO*

Description

Implement Gibbs 2PNO Sampler

Usage

```
Gibbs_2PNO(Y, mu_xi, Sigma_xi_inv, mu_theta, Sigma_theta_inv, burnin,
  chain_length = 10000L)
```

Arguments

Y	A N by J matrix of item responses.
mu_xi	A two dimensional vector of prior item parameter means.
Sigma_xi_inv	A two dimensional identity matrix of prior item parameter VC matrix.
mu_theta	The prior mean for theta.
Sigma_theta_inv	The prior inverse variance for theta.
burnin	The number of MCMC samples to discard.
chain_length	The number of MCMC samples.

Value

Samples from posterior.

Author(s)

Steven Andrew Culpepper

Examples

```
require(fourPNO)
# simulate small 2PNO dataset to demonstrate function
J = 5
N = 100

# Population item parameters
as_t = rnorm(J,mean=2,sd=.5)
bs_t = rnorm(J,mean=0,sd=.5)

# Sampling gs and ss with truncation
gs_t = rbeta(J,1,8)
ps_g = pbeta(1-gs_t,1,8)
ss_t = qbeta(runif(J)*ps_g,1,8)
theta_t = rnorm(N)
Y_t = Y_4pno_simulate(N,J,as=as_t,bs=bs_t,gs=gs_t,ss=ss_t,theta=theta_t)

# Setting prior parameters
mu_theta = 0
Sigma_theta_inv = 1
mu_xi = c(0,0)
alpha_c = alpha_s = beta_c = beta_s = 1
Sigma_xi_inv = solve(2*matrix(c(1,0,0,1), 2, 2))
burnin = 1000

# Execute Gibbs sampler. This should take about 15.5 minutes
out_t <- Gibbs_4PNO(Y_t,mu_xi,Sigma_xi_inv,mu_theta,Sigma_theta_inv,alpha_c,beta_c,alpha_s,
                    beta_s,burnin,rep(1,J),rep(1,J),gwg_reps=5,chain_length=burnin*2)

# Summarizing posterior distribution
```

```
OUT = cbind(apply(out_t$AS[,-c(1:burnin)],1,mean),apply(out_t$BS[,-c(1:burnin)],1,mean),
        apply(out_t$GS[,-c(1:burnin)],1,mean),apply(out_t$SS[,-c(1:burnin)],1,mean),
        apply(out_t$AS[,-c(1:burnin)],1,sd),apply(out_t$BS[,-c(1:burnin)],1,sd),
        apply(out_t$GS[,-c(1:burnin)],1,sd),apply(out_t$SS[,-c(1:burnin)],1,sd) )
OUT = cbind(1:J, OUT)
colnames(OUT) = c('Item','as','bs','gs','ss','as_sd','bs_sd','gs_sd','ss_sd')
print(OUT, digits=3)
```

`Gibbs_4PNO` *Gibbs Implementation of 4PNO*

Description

Internal function to -2LL

Usage

```
Gibbs_4PNO(Y, mu_xi, Sigma_xi_inv, mu_theta, Sigma_theta_inv, alpha_c, beta_c,
  alpha_s, beta_s, burnin, cTF, sTF, gwg_reps, chain_length = 10000L)
```

Arguments

`Y`	A N by J `matrix` of item responses.
`mu_xi`	A two dimensional `vector` of prior item parameter means.
`Sigma_xi_inv`	A two dimensional identity `matrix` of prior item parameter VC matrix.
`mu_theta`	The prior mean for theta.
`Sigma_theta_inv`	The prior inverse variance for theta.
`alpha_c`	The lower asymptote prior 'a' parameter.
`beta_c`	The lower asymptote prior 'b' parameter.
`alpha_s`	The upper asymptote prior 'a' parameter.
`beta_s`	The upper asymptote prior 'b' parameter.
`burnin`	The number of MCMC samples to discard.
`cTF`	A J dimensional `vector` indicating which lower asymptotes to estimate. 0 = exclude lower asymptote and 1 = include lower asymptote.
`sTF`	A J dimensional `vector` indicating which upper asymptotes to estimate. 0 = exclude upper asymptote and 1 = include upper asymptote.
`gwg_reps`	The number of Gibbs within Gibbs MCMC samples for marginal distribution of gamma. Values between 5 to 10 are adequate.
`chain_length`	The number of MCMC samples.

Value

Samples from posterior.

Author(s)

Steven Andrew Culpepper

Examples

```
require(fourPNO)

# Simulate small 4PNO dataset to demonstrate function
J = 5
N = 100

# Population item parameters
as_t = rnorm(J,mean=2,sd=.5)
bs_t = rnorm(J,mean=0,sd=.5)

# Sampling gs and ss with truncation
gs_t = rbeta(J,1,8)
ps_g = pbeta(1-gs_t,1,8)
ss_t = qbeta(runif(J)*ps_g,1,8)
theta_t <- rnorm(N)
Y_t = Y_4pno_simulate(N,J,as=as_t,bs=bs_t,gs=gs_t,ss=ss_t,theta=theta_t)

# Setting prior parameters
mu_theta=0
Sigma_theta_inv=1
mu_xi = c(0,0)
alpha_c=alpha_s=beta_c=beta_s=1
Sigma_xi_inv = solve(2*matrix(c(1,0,0,1),2,2))
burnin = 1000

# Execute Gibbs sampler
out_t = Gibbs_4PNO(Y_t,mu_xi,Sigma_xi_inv,mu_theta,Sigma_theta_inv,alpha_c,beta_c,alpha_s,
                   beta_s,burnin,rep(1,J),rep(1,J),gwg_reps=5,chain_length=burnin*2)

# Summarizing posterior distribution
OUT = cbind(apply(out_t$AS[,-c(1:burnin)],1,mean),apply(out_t$BS[,-c(1:burnin)],1,mean),
            apply(out_t$GS[,-c(1:burnin)],1,mean),apply(out_t$SS[,-c(1:burnin)],1,mean),
            apply(out_t$AS[,-c(1:burnin)],1,sd),apply(out_t$BS[,-c(1:burnin)],1,sd),
            apply(out_t$GS[,-c(1:burnin)],1,sd),apply(out_t$SS[,-c(1:burnin)],1,sd) )

OUT = cbind(1:J,OUT)
colnames(OUT) = c('Item','as','bs','gs','ss','as_sd','bs_sd','gs_sd','ss_sd')
print(OUT,digits=3)
```

---

kappa_initialize *Initialize Thresholds*

Description

Internal function for initializing item thresholds.

Usage

```
kappa_initialize(Ms)
```

Arguments

Ms	A vector with the number of scale values.

Value

A matrix that is a Multivariate Normal distribution

Author(s)

Steven Andrew Culpepper

See Also

Gibbs_4PNO

---

min2LL_4pno *Compute 4PNO Deviance*

Description

Internal function to -2LL

Usage

```
min2LL_4pno(N, J, Y, as, bs, gs, ss, theta)
```

Arguments

N	An int, which gives the number of observations. (> 0)
J	An int, which gives the number of items. (> 0)
Y	A N by J matrix of item responses.
as	A vector of item discrimination parameters.
bs	A vector of item threshold parameters.
gs	A vector of item lower asymptote parameters.
ss	A vector of item upper asymptote parameters.
theta	A vector of prior thetas.

Value

-2LL.

Author(s)

Steven Andrew Culpepper

See Also

Gibbs_4PNO

---

rmvnorm *Generate Random Multivariate Normal Distribution*

Description

Creates a random Multivariate Normal when given number of obs, mean, and sigma.

Usage

```
rmvnorm(n, mu, sigma)
```

Arguments

n	An int, which gives the number of observations. (> 0)
mu	A vector length m that represents the means of the normals.
sigma	A matrix with dimensions m x m that provides the covariance matrix.

Value

A matrix that is a Multivariate Normal distribution

Author(s)

James J Balamuta

Examples

```
#Call with the following data:
rmvnorm(2, c(0,0), diag(2))
```

Total_Tabulate *Calculate Tabulated Total Scores*

Description

Internal function to -2LL

Usage

```
Total_Tabulate(N, J, Y)
```

Arguments

N	An int, which gives the number of observations. (> 0)
J	An int, which gives the number of items. (> 0)
Y	A N by J matrix of item responses.

Value

A vector of tabulated total scores.

Author(s)

Steven Andrew Culpepper

See Also

Gibbs_4PNO

update_2pno *Update 2PNO Model Parameters*

Description

Internal function to update 2PNO parameters

Usage

```
update_2pno(N, J, Y, Z, as, bs, theta, Kaps, mu_xi, Sigma_xi_inv, mu_theta,
  Sigma_theta_inv)
```

Arguments

N	The number of observations.
J	The number of items.
Y	A N by J matrix of item responses.
Z	A matrix N by J of continuous augmented data.
as	A vector of item discrimination parameters.
bs	A vector of item threshold parameters.
theta	A vector of prior thetas.
Kaps	A matrix for item thresholds (used for internal computations).
mu_xi	Prior mean for item parameters.
Sigma_xi_inv	Prior item parameter inverse variance-covariance matrix.
mu_theta	Prior mean for theta.
Sigma_theta_inv	Prior inverse variance for theta.

Value

A list of item parameters.

Author(s)

Steven Andrew Culpepper

See Also

Gibbs_4PNO

---

update_ab_NA *Update a and b Parameters of 2PNO, 3PNO, 4PNO*

Description

Update item slope and threshold

Usage

```
update_ab_NA(N, J, Z, as, bs, theta, mu_xi, Sigma_xi_inv)
```

Arguments

N	An int, which gives the number of observations. (> 0)
J	An int, which gives the number of items. (> 0)
Z	A matrix N by J of continuous augmented data.
as	A vector of item discrimination parameters.
bs	A vector of item threshold parameters.
theta	A vector of prior thetas.
mu_xi	A two dimensional vector of prior item parameter means.
Sigma_xi_inv	A two dimensional identity matrix of prior item parameter VC matrix.

Value

A list of item parameters.

Author(s)

Steven Andrew Culpepper

See Also

Gibbs_4PNO

---

update_ab_norestriction

Update a and b Parameters of 4pno without alpha > 0 Restriction

---

Description

Update item slope and threshold

Usage

```
update_ab_norestriction(N, J, Z, as, bs, theta, mu_xi, Sigma_xi_inv)
```

Arguments

N	An int, which gives the number of observations. (> 0)
J	An int, which gives the number of items. (> 0)
Z	A matrix N by J of continuous augmented data.
as	A vector of item discrimination parameters.
bs	A vector of item threshold parameters.
theta	A vector of prior thetas.
mu_xi	A two dimensional vector of prior item parameter means.
Sigma_xi_inv	A two dimensional identity matrix of prior item parameter VC matrix.

Value

A list of item parameters.

Author(s)

Steven Andrew Culpepper

See Also

Gibbs_4PNO

---

update_theta *Internal Function for Updating Theta in Gibbs Sampler*

Description

Update theta in Gibbs sampler

Usage

```
update_theta(N, Z, as, bs, theta, mu_theta, Sigma_theta_inv)
```

Arguments

N	An int, which gives the number of observations. (> 0)
Z	A matrix N by J of continuous augmented data.
as	A vector of item discrimination parameters.
bs	A vector of item threshold parameters.
theta	A vector of prior thetas.
mu_theta	The prior mean for theta.
Sigma_theta_inv	The prior inverse variance for theta.

Value

A vector of thetas.

Author(s)

Steven Andrew Culpepper

See Also

Gibbs_4PNO

update_WKappaZ_NA *Update Lower and Upper Asymptote Parameters of 4PNO*

Description

Internal function to update item lower and upper asymptote

Usage

```
update_WKappaZ_NA(Y, Ysum, Z, as, bs, gs, ss, theta, Kaps, alpha_c, beta_c,
  alpha_s, beta_s, gwg_reps)
```

Arguments

Y	A N by J matrix of item responses.
Ysum	A vector of item total scores.
Z	A matrix N by J of continuous augmented data.
as	A vector of item discrimination parameters.
bs	A vector of item threshold parameters.
gs	A vector of item lower asymptote parameters.
ss	A vector of item upper asymptote parameters.
theta	A vector of prior thetas.
Kaps	A matrix for item thresholds (used for internal computations).
alpha_c	The lower asymptote prior 'a' parameter.
beta_c	The lower asymptote prior 'b' parameter.
alpha_s	The upper asymptote prior 'a' parameter.
beta_s	The upper asymptote prior 'b' parameter.
gwg_reps	The number of Gibbs within Gibbs MCMC samples for marginal distribution of gamma.

Value

A list of item threshold parameters.

Author(s)

Steven Andrew Culpepper

See Also

Gibbs_4PNO

Y_4pno_simulate *Simulate from 4PNO Model*

Description

Generate item responses under the 4PNO

Usage

```
Y_4pno_simulate(N, J, as, bs, gs, ss, theta)
```

Arguments

N	An int, which gives the number of observations. (> 0)
J	An int, which gives the number of items. (> 0)
as	A vector of item discrimination parameters.
bs	A vector of item threshold parameters.
gs	A vector of item lower asymptote parameters.
ss	A vector of item upper asymptote parameters.
theta	A vector of prior thetas.

Value

A N by J matrix of dichotomous item responses.

Author(s)

Steven Andrew Culpepper

See Also

Gibbs_4PNO

Index