# Package 'graphicalEvidence'

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**Title** Graphical Evidence

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**Description** Computes marginal likelihood in Gaussian graphical models through a novel telescoping block decomposition of the precision matrix which allows estimation of model evidence. The top level function used to estimate marginal likelihood is called evidence, which expects the prior name, data, and relevant prior specific parameters. This package also provides an MCMC prior sampler using the same underlying approach, implemented in prior_sampling, which expects a prior name and prior specific parameters. Both functions also expect the number of burn-in iterations and the number of sampling iterations for the underlying MCMC sampler.

**License** GPL-3

**Imports** Rcpp, parallel, doParallel, foreach, mvtnorm

**LinkingTo** Rcpp, RcppArmadillo

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`graphicalEvidence-package`

*Compute Marginal Likelihood in Gaussian Graphical Models*

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## Description

This package allows estimation of marginal likelihood in Gaussian graphical models through a novel telescoping block decomposition of the precision matrix which allows estimation of model evidence via an application of Chib's method. The currently implemented priors are: Bayesian graphical lasso (BGL), Graphical horseshoe (GHS), Wishart, and G-Wishart.The top level function used to estimate marginal likelihood is `evidence` which expects the prior name, data, and relevant prior specific parameters. This package also provides an MCMC prior sampler for the priors of BGL, GHS, and G-Wishart, implemented in `prior_sampling`, which expects a prior name and prior specific parameters. Both functions also expect the number of burnin iterations and the number of sampling iterations for the underlying MCMC sampler.

Bhadra, A., Sagar, K., Rowe, D., Banerjee, S., & Datta, J. (2022) "Evidence Estimation in Gaussian Graphical Models Using a Telescoping Block Decomposition of the Precision Matrix." <https://arxiv.org/abs/2205.01016>

Chib, S. "Marginal likelihood from the Gibbs output." (1995) <https://www.jstor.org/stable/2291521>

## Details

This package implements marginal estimation for four priors, "Wishart"", Bayesian Graphical Lasso ("BGL"), graphical horseshoe ("GHS"), and "G-Wishart". An MCMC prior sampler is also provided for "BGL", "GHS", and "G-Wishart".

For more information and a faster, less portable implementation, visit the package repository on GitHub: `https://github.com/dp-rho/graphicalEvidence`

## Author(s)

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## References

Bhadra, A., Sagar, K., Rowe, D., Banerjee, S., & Datta, J. (2022) "Evidence Estimation in Gaussian Graphical Models Using a Telescoping Block Decomposition of the Precision Matrix." <https://arxiv.org/abs/2205.01016>

Chib, S. "Marginal likelihood from the Gibbs output." (1995) <https://www.jstor.org/stable/2291521>

## See Also

`test_evidence`: For basic example of functionality

`evidence`: For top level estimation function

`prior_sampling`: For the prior sampler function

## Examples

```
test_results <- test_evidence(num_runs=3, prior_name='G_Wishart')
```

---

`evidence` *Compute Marginal Likelihood using Graphical Evidence*

---

## Description

Computes the marginal likelihood of input data xx under one of the following priors: Wishart, Bayesian Graphical Lasso (BGL), Graphical Horseshoe (GHS), and G-Wishart, specified under prior_name. The number of runs is specified by num_runs, where each run is by default using a random permutation of the columns of xx, as marginal likelihood should be independent of column permutation.

## Usage

```
evidence(
  xx,
  burnin,
  nmc,
  prior_name = c("Wishart", "BGL", "GHS", "G_Wishart"),
  runs = 1,
  print_progress = FALSE,
  permute_columns = TRUE,
  alpha = NULL,
  lambda = NULL,
  V = NULL,
  G = NULL
)
```

## Arguments

| | |
|---|---|
| `xx` | The input data specified by a user for which the marginal likelihood is to be calculated. This should be input as a matrix like object with each individual sample of xx representing one row |
| `burnin` | The number of iterations the MCMC sampler should iterate through and discard before beginning to save results |
| `nmc` | The number of samples that the MCMC sampler should use to estimate marginal likelihood |
| `prior_name` | The name of the prior for which the marginal should be calculated, this is one of 'Wishart', 'BGL', 'GHS', 'G_Wishart' |
| `runs` | The number of complete runs of the graphical evidence method that will be executed. Specifying multiple runs allows estimation of the variance of the estimator and by default will permute the columns of xx such that each run uses a random column ordering, as marginal likelihood should be independent of column permutations |

| | |
|---|---|
| print_progress | A boolean which indicates whether progress should be displayed on the console as each row of the telescoping sum is computed and each run is completed |
| permute_columns | A boolean which indicates whether columns of xx for runs beyond the first should be randomly permuted to ensure that marginal calculation is consistent across different column permutations |
| alpha | A number specifying alpha for the priors of 'Wishart' and 'G_Wishart' |
| lambda | A number specifying lambda for the priors of 'BGL' and 'GHS' prior |
| V | The scale matrix when specifying 'Wishart' or 'G_Wishart' prior |
| G | The adjacency matrix when specifying 'G_Wishart' prior |

## Value

A list of results which contains the mean marginal likelihood, the standard deviation of the estimator, and the raw results in a vector

## Examples

```
# Compute the marginal 10 times with random column permutations of xx at each
# individual run for G-Wishart prior using 2,000 burnin and 10,000 sampled
# values at each call to the MCMC sampler
g_params <- gen_params_evidence('G_Wishart')
marginal_results <- evidence(
  g_params$x_mat, 2e3, 1e4, 'G_Wishart', 3, alpha=2,
  V=g_params$scale_mat, G=g_params$g_mat
)
```

---

# gen_params_evidence *Generate Test Parameters*

---

## Description

Generates predetermined parameters for testing the functionality of the graphical evidence method

## Usage

```
gen_params_evidence(prior_name = c("Wishart", "BGL", "GHS", "G_Wishart"))
```

## Arguments

| | |
|---|---|
| prior_name | The name of the prior for being tested with preexisting test parameters, this is one of 'Wishart', 'BGL', 'GHS', 'G_Wishart' |

## Value

A list of matrices representing test parameters dependent on the prior specified in prior_name

## Examples

```
# Generate test parameter matrices for G-Wishart prior
gen_params_evidence('G_Wishart')
```

---

`graphical_evidence_G_Wishart` *Compute Marginal Likelihood using Graphical Evidence under G Wishart*

---

## Description

Computes the marginal likelihood of input data xx under G-Wishart prior using graphical evidence.

## Usage

```
graphical_evidence_G_Wishart(
  xx,
  burnin,
  nmc,
  alpha,
  V,
  G,
  print_progress = FALSE
)
```

## Arguments

| | |
|---|---|
| `xx` | The input data specified by a user for which the marginal likelihood is to be calculated. This should be input as a matrix like object with each individual sample of xx representing one row |
| `burnin` | The number of iterations the MCMC sampler should iterate through and discard before beginning to save results |
| `nmc` | The number of samples that the MCMC sampler should use to estimate marginal likelihood |
| `alpha` | A number specifying alpha for G-Wishart prior |
| `V` | The scale matrix of G-Wishart prior |
| `G` | The adjacency matrix of G-Wishart prior |
| `print_progress` | A boolean which indicates whether progress should be displayed on the console as each row of the telescoping sum is computed |

## Value

An estimate for the marginal likelihood under G-Wishart prior with the specified parameters

## Examples

```
# Compute the marginal likelihood of xx for G-Wishart prior using
# 2,000 burnin and 10,000 sampled values at each call to the MCMC sampler
g_params <- gen_params_evidence('G_Wishart')
marginal_results <- graphical_evidence_G_Wishart(
  g_params$x_mat, 2e3, 1e4, 2, g_params$scale_mat, g_params$g_mat
)
```

---

`graphical_evidence_rmatrix` *Compute Marginal Likelihood using Graphical Evidence for Wishart, BGL, and GHS*

---

## Description

Computes the marginal likelihood of input data xx under one of the following priors: Wishart, Bayesian Graphical Lasso (BGL), and Graphical Horseshoe (GHS), specified under prior_name.

## Usage

```
graphical_evidence_rmatrix(
  xx,
  burnin,
  nmc,
  prior_name = c("Wishart", "BGL", "GHS"),
  lambda = 0,
  alpha = 0,
  V = 0,
  print_progress = FALSE
)
```

## Arguments

| | |
|---|---|
| `xx` | The input data specified by a user for which the marginal likelihood is to be calculated. This should be input as a matrix like object with each individual sample of xx representing one row |
| `burnin` | The number of iterations the MCMC sampler should iterate through and discard before beginning to save results |
| `nmc` | The number of samples that the MCMC sampler should use to estimate marginal likelihood |
| `prior_name` | The name of the prior for which the marginal should be calculated, this is one of 'Wishart', 'BGL', 'GHS' |
| `lambda` | A number specifying lambda for the priors of 'BGL' and 'GHS' prior |
| `alpha` | A number specifying alpha for the priors of 'Wishart' |
| `V` | The scale matrix when specifying 'Wishart' |
| `print_progress` | A boolean which indicates whether progress should be displayed on the console as each row of the telescoping sum is computed |

## Value

An estimate for the marginal likelihood under specified prior with the specified parameters

## Examples

```
# Compute the marginal likelihood of xx for GHS prior using 1,000
# burnin and 5,000 sampled values at each call to the MCMC sampler
g_params <- gen_params_evidence('GHS')
marginal_results <- graphical_evidence_rmatrix(
  g_params$x_mat, 1e3, 5e3, 'GHS', lambda=1
)
```

---

# prior_sampling *Sample The Precision Matrix*

---

## Description

Takes specified prior_name and relevant parameters to sample the precision matrix nmc times after discarding the first number of runs specified by burnin.

## Usage

```
prior_sampling(
  p,
  burnin,
  nmc,
  prior_name = c("BGL", "GHS", "G_Wishart"),
  G = NULL,
  V = NULL,
  alpha = NULL,
  lambda = NULL
)
```

## Arguments

| | |
|---|---|
| p | The dimension of the precision matrix that will be sampled |
| burnin | The number of iterations the MCMC sampler should iterate through and discard before beginning to save results |
| nmc | The number of samples that will be drawn |
| prior_name | The name of the prior for which the marginal should be calculated, this is one of 'Wishart', 'BGL', 'GHS', 'G_Wishart' |
| G | The adjacency matrix when specifying 'G_Wishart' prior |
| V | The scale matrix when specifying 'Wishart' or 'G_Wishart' prior |
| alpha | A number specifying alpha for the priors of 'Wishart' and 'G_Wishart' |
| lambda | A number specifying lambda for the priors of 'BGL' and 'GHS' prior |

## Value

An array of dim nmc x p x p where each p x p slice is one sample of the precision matrix

## Examples

```
# Draw 5000 samples of the precision matrix for GHS prior distribution with
# parameter lambda set to 1
prior_sampling(5, 1e3, 5e3, 'GHS', lambda=1)
```

---

# set_seed_evidence *Set the Random Seed*

---

## Description

Sets the random seed of both the R session (using set.seed) and the compiled sampler, as both samplers are used during any calls to evidence(...) or prior_sampling(...)

## Usage

```
set_seed_evidence(seed)
```

## Arguments

| | |
|---|---|
| seed | a random seed that will be passed to the interpreted random number generator using set.seed, and will be passed to the compiled random number generator using private Rcpp package function set_seed |

## Value

No return value, this function is called to set the random seed.

## Examples

```
set_seed_evidence(42)
```

test_evidence *Test Graphical Evidence*

## Description

Tests any of the allowed priors with preexisting test inputs which should yield reproducible results, as the random seed is reset during this function call

## Usage

```
test_evidence(
  num_runs,
  prior_name = c("Wishart", "BGL", "GHS", "G_Wishart"),
  input_seed = NULL
)
```

## Arguments

| | |
|---|---|
| num_runs | An integer number that specifies how many runs of graphical evidence will be executed on the test parameters, as multiple runs allows us to quantify uncertainty on the estimator. |
| prior_name | The name of the prior for being tested with preexisting test parameters, this is one of 'Wishart', 'BGL', 'GHS', 'G_Wishart' |
| input_seed | An integer value that will be used as a random seed to make outputs repeatable. |

## Value

A list of results which contains the mean marginal likelihood, the standard deviation of the estimator, and the raw results in a vector

## Examples

```
# Compute the marginal 10 times with random column permutations of the
# preexisting test parameters for G-Wishart prior
test_evidence(num_runs=3, 'G_Wishart')
```

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