

# Package ‘DIFM’

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**Type** Package

**Title** Dynamic ICAR Spatiotemporal Factor Models

**Version** 1.0

**Date** 2024-04-07

**Description** Bayesian factor models are effective tools for dimension reduction. This is especially applicable to multivariate large-scale datasets. It allows researchers to understand the latent factors of the data which are the linear or non-linear combination of the variables. Dynamic Intrinsic Conditional Autocorrelative Priors (ICAR) Spatiotemporal Factor Models 'DIFM' package provides function to run Markov Chain Monte Carlo (MCMC), evaluation methods and visual plots from Shin and Ferreira (2023)<[doi:10.1016/j.spasta.2023.100763](https://doi.org/10.1016/j.spasta.2023.100763)>. Our method is a class of Bayesian factor model which can account for spatial and temporal correlations. By incorporating these correlations, the model can capture specific behaviors and provide predictions.

**License** GPL (>= 2)

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DIFM-package

*Dynamic ICAR Spatiotemporal Factor Models*

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## Description

Bayesian factor models are effective tools for dimension reduction. This is especially applicable to multivariate large-scale datasets. It allows researchers to understand the latent factors of the data which are the linear or non-linear combination of the variables. Dynamic Intrinsic Conditional Autocorrelative Priors (ICAR) Spatiotemporal Factor Models 'DIFM' package provides function to run Markov Chain Monte Carlo (MCMC), evaluation methods and visual plots from Shin and Ferreira (2023)<doi:10.1016/j.spasta.2023.100763>. Our method is a class of Bayesian factor model which can account for spatial and temporal correlations. By incorporating these correlations, the model can capture specific behaviors and provide predictions.

## Details

Package: BCFM2

Type: Package

Version: 1.0

Date: 2023-02-20

License: GPL(>=2)

**Author(s)**

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**References**

Shin, H. and Ferreira, M. (2023). "Dynamic ICAR Spatiotemporal Factor Models." *Spatial Statistics*, 56, 100763

Lopes, H. and West, M. (2004). "Bayesian Model Assessment in Factor Analysis." *Statistica Sinica*, 14, 41–67.

Prado, R., Ferreira, M. A. R., and West, M. (2021). *Time Series: Modeling, Computation, and Inference*. 2nd ed. Boca Raton: CRC Press.

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buildH

*Spatial dependence matrix of the factor loadings*

---

**Description**

It computes the spatial covariance and precision matrix of the neighboring subregions using Intrinsic Autoregressive Conditional (ICAR) process.

**Usage**

```
buildH(areapoly, permutation = NA)
```

**Arguments**

areapoly      The polygon of the areas. We can obtain this through readOGR function from sp matrix.

permutation      Permutation order of the subregions

**Details**

The off-diagonal values are -1 when two subregions are neighbors. Otherwise, we assign 0. The diagonal values are the sum of the values of its own row.

**Value**

A list of two matrices: Precision matrix H and the covariance matrix obtained through Moore-Penrose inverse of H.

---

difm.hyp.parm                      *Hyperparameters for DIFM*

---

### Description

Sets the hyperparameters to generate Gibbs sampler of DIFM

### Usage

```
difm.hyp.parm(
  model.attributes,
  n.tau = 2.2,
  n.s2.tau = 0.1,
  n.sigma = 2.2,
  n.s2.sigma = 0.1,
  Hlist,
  Psi.size = 0.01
)
```

### Arguments

model.attributes	Model attributes from difm.model.attributes
n.tau	Shape parameter for tau
n.s2.tau	Rate parameter for tau
n.sigma	Shape parameter for sigma squared
n.s2.sigma	Rate parameter for sigma squared
Hlist	Neighborhood matrix
Psi.size	The magnitude of covariance for the evolution matrix

### Value

A list of hyperparameters of tau, W, sigma, and theta.

---

difm.model.attributes    *Initialize model attributes for DIFM*

---

### Description

It initialize the basic parameters and model attributes for DIFM

### Usage

```
difm.model.attributes(data, n.iter, n.factors, G0)
```

**Arguments**

<code>data</code>	The dataset
<code>n.iter</code>	Number of iterations
<code>n.factors</code>	Number of factors to run DIFM
<code>G0</code>	The basic evolution matrix for one factor

**Value**

A list of number of timepoints, subregions, factors, matrix of evolution matrix, and matrix to extract common factors.

---

DIFMcpp

---

*Run Dynamic ICAR Factors Model (DIFM), with C++ codes*


---

**Description**

This function runs Dynamic ICAR factors Model (DIFM), simulated from C++ codes

**Usage**

```
DIFMcpp(model.attributes, hyp.parm, data, every = 1, verbose = TRUE)
```

**Arguments**

<code>model.attributes</code>	Model attributes from <code>difm.model.attributes</code>
<code>hyp.parm</code>	Hyperparameters from <code>difm.hyp.parm</code>
<code>data</code>	The dataset
<code>every</code>	Save every iterations to final result
<code>verbose</code>	Print out the iteration process

**Value**

The Gibbs sampler of DIFM

DIFMR

*Run Dynamic ICAR Factors Model (DIFM)*

---

**Description**

This function runs Dynamic ICAR factors Model (DIFM)

**Usage**

```
DIFMR(model.attributes, hyp.parm, data, every = 1, verbose = TRUE)
```

**Arguments**

model.attributes	Model attributes from difm.model.attributes
hyp.parm	Hyperparameters from difm.hyp.parm
data	The dataset
every	Save every iterations to final result
verbose	Print out the iteration process

**Value**

The Gibbs sampler of DIFM

---

marginal.d

*Marginal predictive density*

---

**Description**

It calculates the marginal density (Lewis and Raftery, 1997) from the DIFM sample using R.

**Usage**

```
marginal.d(  
  data,  
  model.attributes,  
  hyp.parm,  
  Gibbs,  
  burnin = NA,  
  verbose = TRUE  
)
```

**Arguments**

data	The dataset
model.attributes	Model attributes generated from difm.model.attributes.
hyp.parm	Hyperparameters generated from difm.hyp.parm.
Gibbs	Result of Gibbs sampler from DIFM function.
burnin	Burn-in period. If not specified, one tenths of the iterations will be the burn-in period.
verbose	Print out the iteration process.

**Value**

Metropolis-Laplace estimator of the Marginal density

---

marginal_d_cpp	<i>Marginal predictive density</i>
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---

**Description**

It calculates the marginal density (Lewis and Raftery, 1997) from the DIFM sample using C++.

**Usage**

```
marginal_d_cpp(data, attributes, hyp_parm, Gibbs, burnin = -1L, verbose = TRUE)
```

**Arguments**

data	The dataset
attributes	Model attributes generated from difm.model.attributes.
hyp_parm	Hyperparameters generated from difm.hyp.parm.
Gibbs	Result of Gibbs sampler from DIFM function.
burnin	Burn-in period. If not specified, one tenths of the iterations will be the burn-in period.
verbose	Print out the process.

**Value**

A list of 4 items: Laplace-Metropolis predictive density of the given DIFM, integrated likelihood, the maximum of the predictive densities and determinant of the covariance matrix of the parameters.

---

permutation.order	<i>Order of permutation by the largest absolute value in each eigenvector</i>
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---

**Description**

It finds the vector of permutation to permute data by its largest absolute value in each eigenvector. It sets the order by specified number of factors, and the rest is ordered as they were.

**Usage**

```
permutation.order(data, n.factors)
```

**Arguments**

data	The dataset
n.factors	Number of factors

**Value**

The numeric vector of permutation

---

permutation.scale	<i>Permute the dataset by the largest absolute value in each eigenvector, and scale</i>
-------------------	---

---

**Description**

It finds the vector of permutation to permute data by its largest absolute value in each eigenvector. It sets the order by specified number of factors, and the rest is ordered as they were. The data is permuted, and if needed, scaled.

**Usage**

```
permutation.scale(data, n.factors, return.scale = FALSE)
```

**Arguments**

data	The dataset
n.factors	Number of factors
return.scale	Scale data after permutation

**Value**

The permuted and standardized dataset, either in matrix or array.



---

plot_B.CI	<i>Credible interval plot of factor loadings</i>
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---

### Description

The functions builds a column-wise plots of factor loadings. The parameters fixed at 1 are displayed with red dashed vertical lines.

### Usage

```
plot_B.CI(
  Gibbs,
  true.val = NA,
  burnin = NA,
  permutation = NA,
  main.bool = TRUE,
  layout.dim = NA
)
```

### Arguments

Gibbs	Result of Gibbs sampler from DIFM function
true.val	True values of factor loadings. If not available, NA.
burnin	Number of burn-in. If not specified, it uses the first tenths as burn-in period.
permutation	Permutation of variables. If not specified, no permutation.
main.bool	Add title of the plots.
layout.dim	Dimension of panel layout for multiple factor loadings. If not specified, factor loadings plots are layout in one column.

### Value

Factor loadings credible interval plots

---

plot_B.spatial	<i>Spatial plots of factor loadings</i>
----------------	---

---

### Description

The functions builds maps of factor loadings.

**Usage**

```
plot_B.spatial(
  Gibbs,
  areapoly,
  burnin = NA,
  permutation = NA,
  main.bool = TRUE,
  layout.dim = NA
)
```

**Arguments**

Gibbs	Result of Gibbs sampler from DIFM function.
areapoly	The polygon of the areas. We can obtain this through readOGR function from sp package.
burnin	Number of burn-in. If not specified, it uses the first tenths as burn-in period.
permutation	Permutation of variables. If not specified, no permutation.
main.bool	Add title of the plots.
layout.dim	Dimension of panel layout for multiple factor loadings. If not specified, factor loadings plots are layout in one column.

**Value**

Factor loadings map plots

---

plot_sigma2.CI	<i>A credible interval plot of posterior of sigma squared</i>
----------------	---

---

**Description**

It returns a credible interval plot of idiosyncratic variance, sigma squared. The lines are 95

**Usage**

```
plot_sigma2.CI(Gibbs, burnin = NA, permutation = NA, main.bool = TRUE)
```

**Arguments**

Gibbs	Result of Gibbs sampler from DIFM function.
burnin	Number of burn-in. If not specified, it uses the first tenths as burn-in period.
permutation	Permutation of variables. If not specified, no permutation.
main.bool	Add title of the plots.

**Value**

A credible interval plot of sigma squared

---

plot_tau.CI	<i>Credible interval plot of factor loadings variance</i>
-------------	---

---

**Description**

It returns a credible interval plot of factor loadings covariance, tau. The lines are 95

**Usage**

```
plot_tau.CI(Gibbs, burnin = NA, true.val = NA, main.bool = TRUE)
```

**Arguments**

Gibbs	Result of Gibbs sampler from DIFM function.
burnin	Number of burn-in. If not specified, it uses the first tenths as burn-in period.
true.val	True values of tau. If not available, NA.
main.bool	Add title of the plots.

**Value**

Credible interval plot of tau

---

plot_X.CI	<i>Credible interval plot of common factors</i>
-----------	---

---

**Description**

The functions builds the plot of 95% confidence intervals of the common realizations, X. The black solid lines are the posterior mean and the dashed lines are the 95% confidence intervals.

**Usage**

```
plot_X.CI(Gibbs, burnin = NA, main.bool = FALSE, layout.dim = NA)
```

**Arguments**

Gibbs	Result of Gibbs sampler from DIFM function.
burnin	Number of burn-in. If not specified, it uses the first tenths as burn-in period.
main.bool	Add title of the plots.
layout.dim	Dimension of panel layout for multiple common factors. If not specified, common factor plots are layout in one column.

**Value**

Credible interval plots of common factors

---

Property

*Property crime in United States*

---

**Description**

A subset of data of property crime per 100,000 people in western states from 1960 to 2019.

**Usage**

Property

**Format**

## 'Property' A data frame with 60 rows and 11 columns:

**AZ** Arizona

**CA** California

**CO** Colorado

**ID** Idaho

**MT** Montana

**NV** Nevada

**NM** New Mexico

**OR** Oregon

**UT** Utah

**WA** Washington

**WY** Wyoming ...

**Source**

<<https://www.disastercenter.com/crime/>>

---

Violent

*Violent crime data in United States*

---

**Description**

A subset of data of violent crime per 100,000 people in western states from 1960 to 2019.

**Usage**

Violent

**Format**

## 'Violent' A data frame with 60 rows and 11 columns:

**AZ** Arizona

**CA** California

**CO** Colorado

**ID** Idaho

**MT** Montana

**NV** Nevada

**NM** New Mexico

**OR** Oregon

**UT** Utah

**WA** Washington

**WY** Wyoming ...

**Source**

<<https://www.disastercenter.com/crime/>>

---

WestStates

*Westen states in United States*

---

**Description**

A sp map data of the western states in United States

**Usage**

WestStates

**Format**

## 'WestStates' A SpatialPolygonsDataFrame data of the western states in United States

**FID** The number ID of the western states

**State\_Code** Abbreviations of the state names

**State\_Name** Names of the states A SpatialPolygonsDataFrame data of the western states in United States

**Source**

<<https://www.census.gov/geographies/mapping-files/time-series/geo/carto-boundary-file.html>>

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