Package: CARME (via r-universe)

October 29, 2026

Title CAR-MM Modelling in Stan

Version 0.1.1

Description 'Stan' based functions to estimate CAR-MM models. These models allow to estimate Generalised Linear Models with CAR (conditional autoregressive) spatial random effects for spatially and temporally misaligned data, provided a suitable Multiple Membership matrix. The main references are Gramatica, Liverani and Congdon (2023) <doi:10.1214/23-BA1370>, Petrof, Neyens, Nuyts, Nackaerts, Nemery and Faes (2020) <doi:10.1002/sim.8697> and Gramatica, Congdon and Liverani <doi:10.1111/rssc.12480>.

License GPL (>= 3)

Encoding UTF-8

RoxygenNote 7.2.3

Biarch true

Depends R (>= 3.5.0)

Imports methods, Rcpp (>= 0.12.0), rstan (>= 2.18.1), MASS, expm, stats, rstantools

LinkingTo BH (>= 1.66.0), Rcpp (>= 0.12.0), RcppEigen (>= 0.3.3.3.0), rstan (>= 2.18.1), StanHeaders (>= 2.18.0), RcppParallel (>= 5.0.1)

SystemRequirements GNU make

NeedsCompilation yes

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`CARME-package` *The 'CARME' package.*

Description

CAR-MM modelling in Stan

References

Stan Development Team (2023). RStan: the R interface to Stan. R package version 2.26.11. https://mc-stan.org

Marco Gramatica. Silvia Liverani. Peter Congdon. Structure Induced by a Multiple Membership Transformation on the Conditional Autoregressive Model. Bayesian Analysis Advance Publication 1 - 25, 2023. https://doi.org/10.1214/23-BA1370

Petrof, O, Neyens, T, Nuyts, V, Nackaerts, K, Nemery, B, Faes, C. On the impact of residential history in the spatial analysis of diseases with a long latency period: A study of mesothelioma in Belgium. Statistics in Medicine. 2020; 39: 3840– 3866. https://doi.org/10.1002/sim.8697

Marco Gramatica, Peter Congdon, Silvia Liverani, Bayesian Modelling for Spatially Misaligned Health Areal Data: A Multiple Membership Approach, Journal of the Royal Statistical Society Series C: Applied Statistics, Volume 70, Issue 3, June 2021, Pages 645–666, https://doi.org/10.1111/rssc.12480

car_mm *CAR-MM prior model*

Description

CAR-MM prior model

Usage

```
car_mm(d_list, ...)
```

Arguments

d_list	List of data inputs for the stan model.
...	Arguments passed to `rstan::sampling` (e.g. iter, chains).

Value

An object of class `stanfit` returned by `rstan::sampling`

References

Marco Gramatica. Silvia Liverani. Peter Congdon. "Structure Induced by a Multiple Membership Transformation on the Conditional Autoregressive Model." Bayesian Analysis Advance Publication 1 - 25, 2023. https://doi.org/10.1214/23-BA1370

Petrof, O, Neyens, T, Nuyts, V, Nackaerts, K, Nemery, B, Faes, C. On the impact of residential history in the spatial analysis of diseases with a long latency period: A study of mesothelioma in Belgium. Statistics in Medicine. 2020; 39: 3840– 3866. https://doi.org/10.1002/sim.8697

Examples

```
set.seed(455)

#---- Load data
data(W_sel)
## Number of areas
n <- nrow(W_sel)
## Number of memberships
m <- 153

#---- Simulate covariates
X <- cbind(rnorm(nrow(W_sel)), rnorm(nrow(W_sel)))
## Min-max normalisation
X_cent <- apply(X, 2, function(x) (x - min(x))/diff(range(x)))

#---- Simulate MM matrix
w_ord <- c(.5, .35, .15) # Weight of each neighbours orders
ord <- length(w_ord) - 1 # Order of neighbours to include
```

```
H_sel_sim <- sim_MM_matrix(
  W = W_sel, m = m, ord = ord, w_ord = w_ord, id_vec = rep(1, nrow(W_sel))
)

#---- Simulate outcomes
## Linear term parameters
gamma <- -.5 # Intercept
beta <- c(1, .5) # Covariates coefficients
## CAR random effects
phi_car <- sim_car(W = W_sel, alpha = .9, tau = 5)
# Areal log relative risks
l_RR <- X_cent %*% beta + phi_car
## Membership log relative risks
l_RR_mm <- as.numeric(apply(H_sel_sim, 1, function(x) x %*% l_RR))
## Expected rates
exp_rates <- rpois(m, lambda = 20)
## Outcomes
y <- rpois(m, lambda = exp_rates*exp(l_RR_mm))

#---- Create dataset for stan function
d_sel <- list(
  # Number of areas
  n = nrow(W_sel),
  # Covariates
  k = ncol(X_cent),
  X_cov = X_cent,
  # Adjacency
  W_n = sum(W_sel) / 2,
  # Number of neighbour pairs
  W = W_sel,
  # Memberships
  m = nrow(H_sel_sim),
  H = H_sel_sim,
  # Outcomes
  y = y,
  log_offset = log(exp_rates),
  # Prior parameters
  ## Intercept (mean and sd of normal prior)
  mu_gamma = 0, sigma_gamma = 1,
  ## Covariates (mean and sd of normal prior)
  mu_beta = 0, sigma_beta = 1,
  ## Marginal precision gamma prior
  tau_shape = 2,
  tau_rate = 0.2
)

#---- HMC parameters
niter <- 1E4
nchains <- 4

#---- Stan sampling
fit <- car_mm(
  d_list = d_sel,
```

```
  # arguments passed to sampling
  iter = niter, chains = nchains, refresh = 500,
  control = list(adapt_delta = .99, max_treedepth = 15)
)
```

`sim_car` *Simulation of proper CAR random effects*

Description

`sim_car` returns a vector of CAR distributed random effects

Usage

```
sim_car(W, alpha = 0.5, tau = 5)
```

Arguments

`W`	Symmetric adjacency matrix of size `n`
`alpha`	properness parameter between 0 and 1. Defaults to 0.5
`tau`	marginal precision. Defaults to 5

Value

a vector of length `n`

References

Jin, X., Carlin, B.P. and Banerjee, S. (2005), Generalized Hierarchical Multivariate CAR Models for Areal Data. Biometrics, 61: 950-961. https://doi.org/10.1111/j.1541-0420.2005.00359.x

Examples

```
data(W_sel)
sim_car(W = W_sel, alpha = .9, tau = 5)
```

`sim_MM_matrix` *Simulation of MM matrix based*

Description

`sim_MM_matrix` returns a multiple membership matrix simulated based on an adjacency matrix according to the method described in

Usage

```
sim_MM_matrix(W, m, ord = 3, w_ord, id_vec, excess_areas = FALSE, red_areas)
```

Arguments

`W`	Symmetric adjacency matrix of size `n`
`m`	Integer. Number of membership to simulate
`ord`	Integer. Maximum order of neighbours to be used to simulate the memberships based on the adjacency matrix `W`
`w_ord`	A vector of length `ord` that specifies the weights of each order of neighbours
`id_vec`	Vector of zeros and ones of length `n`. Defaults to a vector of ones. It indicates whether an area is included in the simulation of a membership
`excess_areas`	if different from FALSE it indicates the indices of the areas to reuse in simulating memberships, whenever `m > n`. It defaults to FALSE, and if omitted randomly selects without replacement (if `m - n <= n`, otherwise with replacement) a subset of areas
`red_areas`	vector of indices of areas to use if `m < n`

Value

an m x n matrix of weights

References

Marco Gramatica. Silvia Liverani. Peter Congdon. "Structure Induced by a Multiple Membership Transformation on the Conditional Autoregressive Model." Bayesian Analysis Advance Publication 1 - 25, 2023. https://doi.org/10.1214/23-BA1370

Examples

```
set.seed(455)

#---- Load data
data(W_sel)
## Number of areas
n <- nrow(W_sel)
## Number of memberships
```

```
m <- 153

#---- Simulate MM matrix
w_ord <- c(.5, .35, .15) # Weight of each neighbours orders
ord <- length(w_ord) - 1 # Order of neighbours to include
H_sel_sim <- sim_MM_matrix(
  W = W_sel, m = m, ord = ord, w_ord = w_ord, id_vec = rep(1, nrow(W_sel))
)
```

`W_sel` *Adjacency matrix for the South East London set of MSOAs*

Description

Adjacency matrix of 152 MSOAs in South East London, used for the data analysis in the paper "Structure induced by a multiple membership transformation on the Conditional Autoregressive model". Column and rows names indicate the MSOA code.

Usage

```
data(W_sel)
```

Format

A 152x152 symmetric matrix

References

Marco Gramatica. Silvia Liverani. Peter Congdon. "Structure Induced by a Multiple Membership Transformation on the Conditional Autoregressive Model." Bayesian Analysis Advance Publication 1 - 25, 2023. https://doi.org/10.1214/23-BA1370

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