

Package ‘CARME’

May 7, 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](https://doi.org/10.1214/23-BA1370)>, Petrof, Neyens, Nuyts, Nackaerts, Nemery and Faes (2020) <[doi:10.1002/sim.8697](https://doi.org/10.1002/sim.8697)> and Gramatica, Congdon and Liverani <[doi:10.1111/rssc.12480](https://doi.org/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

Author Marco Gramatica [aut, cre] (ORCID: <<https://orcid.org/0000-0002-6374-0933>>),
Silvia Liverani [aut] (ORCID: <<https://orcid.org/0000-0002-1870-3017>>),
Peter Congdon [aut] (ORCID: <<https://orcid.org/0000-0003-1934-9205>>)

Maintainer Marco Gramatica <gramaticamarco@gmail.com>

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CARME-package	<i>The 'CARME' package.</i>
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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	<i>CAR-MM prior model</i>
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Description

CAR-MM prior model

Usage

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

Arguments

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

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	<i>Simulation of MM matrix based</i>
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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 $m - n \leq n$, otherwise with replacement) a subset of areas
red_areas	vector of indices of areas to use if $m < n$

Value

an $m \times n$ 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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