

# Package ‘CARME’

July 21, 2025

**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

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**Repository** CRAN

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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>

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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)
)

```

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sim\_car

*Simulation of proper CAR random effects*


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## 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)
```

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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))
)
```

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W\_sel

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

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**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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