# Package 'spatemR'

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**Type** Package

**Title** Generalized Spatial Autoregresive Models for Mean and Variance

**Version** 1.0.0

**Description**

Modeling spatial dependencies in dependent variables, extending traditional spatial regression approaches. It allows for the joint modeling of both the mean and the variance of the dependent variable, incorporating semiparametric effects in both models. Based on generalized additive models (GAM), the package enables the inclusion of non-parametric terms while maintaining the classical theoretical framework of spatial regression. Additionally, it implements the Generalized Spatial Autoregression (GSAR) model, which extends classical methods like logistic Spatial Autoregresive Models (SAR), probit Spatial Autoregresive Models (SAR), and Poisson Spatial Autoregresive Models (SAR), offering greater flexibility in modeling spatial dependencies and significantly improving computational efficiency and the statistical properties of the estimators. Related work includes: a) J.D. Toloza-Delgado, Melo O.O., Cruz N.A. (2024). ``Joint spatial modeling of mean and non-homogeneous variance combining semiparametric SAR and GAMLSS models for hedonic prices". <doi:10.1016/j.spasta.2024.100864>. b) Cruz, N. A., Toloza-Delgado, J. D., Melo, O. O. (2024). ``Generalized spatial autoregressive model". <doi:10.48550/arXiv.2412.00945>.

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GEESAR *Generalized Estimating Equations with Spatial Autoregressive Components*

---

## Description

'GEESAR' estimates generalized estimating equations (GEE) incorporating spatial autoregressive (SAR) components. It extends GEE models to account for spatial dependence in the response variable.

## Usage

```
GEESAR(
  formula,
  family = gaussian(),
  weights = NULL,
  data,
  W,
  start = NULL,
  toler = 1e-04,
  maxit = 200,
  trace = FALSE
)
```

## Arguments

| | |
|---|---|
| formula | A formula specifying the model structure (response ~ predictors). |
| family | A description of the error distribution and link function. Default is 'gaussian()'. |
| weights | Optional vector of prior weights. Must be positive. |
| data | A data frame containing the variables in the model. |
| W | A spatial weights matrix defining the spatial dependence structure. |
| start | Optional starting values for parameter estimation. |
| toler | Convergence tolerance for iterative optimization. Default is '1e-05'. |
| maxit | Maximum number of iterations for model fitting. Default is '50'. |
| trace | Logical; if 'TRUE', prints iteration details. Default is 'FALSE'. |

## Details

The function estimates a spatially autoregressive GEE model by iteratively updating the spatial dependence parameter (‘rho‘) and regression coefficients (‘beta‘). The estimation follows a quasi-likelihood approach using iterative weighted least squares (IWLS).

The function supports common GLM families (‘gaussian‘, ‘binomial‘, ‘poisson‘, ‘Gamma‘, ‘inverse.gaussian‘) and their quasi-likelihood equivalents.

## Value

A list of class ‘"GEESAR"‘ containing:

| | |
|---|---|
| `coefficients` | Estimated regression coefficients. |
| `rho` | Estimated spatial autoregressive parameter. |
| `fitted.values` | Predicted values from the model. |
| `linear.predictors` | Linear predictor values (‘X * beta‘). |
| `prior.weights` | Weights used in estimation. |
| `y` | Observed response values. |
| `formula` | Model formula. |
| `call` | Function call used to fit the model. |
| `data` | Data used in the model. |
| `converged` | Logical indicating whether the algorithm converged. |
| `logLik` | Quasi-log-likelihood of the fitted model. |
| `deviance` | Residual deviance. |
| `df.residual` | Residual degrees of freedom. |
| `phi` | Dispersion parameter estimate. |
| `CIC` | Corrected Information Criterion. |
| `RJC` | Robust Jackknife Correction. |

## Source

https://doi.org/10.48550/arXiv.2412.00945

## References

Cruz, N. A., Toloza-Delgado, J. D., & Melo, O. O. (2024). Generalized spatial autoregressive model. arXiv preprint arXiv:2412.00945.

## See Also

`glm`, `gee`, `spdep`

## Examples

```
library(spdep)
library(sp)
data(meuse)
sp::coordinates(meuse) <- ~x+y
W <- spdep::nb2mat(knn2nb(knearneigh(meuse, k=5)), style="W")
fit <- GEESAR(cadmium ~ dist + elev, family=poisson(), data=meuse, W=W)
summary_SAR(fit)
```

---

`Hurdle_GEESAR` *Hurdle Model using GEESAR*

---

## Description

This function fits a hurdle model using GEESAR, consisting of: (1) A logit model for zero vs. non-zero responses. (2) A truncated Poisson model for positive counts.

## Usage

```
Hurdle_GEESAR(
  formula,
  data,
  W,
  weights = NULL,
  toler = 1e-05,
  maxit = 200,
  trace = FALSE
)
```

## Arguments

| | |
|---|---|
| `formula` | A formula specifying the model. |
| `data` | The dataset. |
| `W` | The spatial weight matrix. |
| `weights` | Optional weights. |
| `toler` | Convergence tolerance. |
| `maxit` | Maximum number of iterations. |
| `trace` | Logical. If TRUE, prints progress. |

## Value

A list containing the logit and Poisson-truncated models.

## Examples

```
set.seed(123)
n <- 100
x <- rnorm(n)
y <- rpois(n, lambda = exp(0.5 * x))
y[rbinom(n, 1, 1/(1+exp(-0.5*x)))] <- 0  # Introduce zeros
W <- matrix(rbinom(n^2,1,0.2), n, n)  # Example spatial weight matrix
diag(W) <- 0
rtot <- rowSums(W)
W <- W/ifelse(rtot==0, 0.1, rtot)
model <- Hurdle_GEESAR(y ~ x, data = data.frame(y, x), W = W)
summary_SAR(model$logit_model)
summary_SAR(model$poisson_truncated_model)
```

---

# print.summary.GEESAR *Print Method for Summary of GEESAR Models*

---

## Description

This method prints a formatted summary of a 'summary.GEESAR' object, including details of the model coefficients, rho, dispersion, and other statistics.

## Usage

```
## S3 method for class 'summary.GEESAR'
print(x, ...)
```

## Arguments

| | |
|---|---|
| x | An object of class 'summary.GEESAR'. |
| ... | Additional arguments (currently unused). |

## Value

Print a summary for the specified Generalized Spatial Autoregresive Model class.

## print.summary.SARARgamlss *Print Method for Summary of SARARgamlss Models*

### Description

This method prints a formatted summary of a 'summary.SARARgamlss' object, including details of the GAMLSS model, spatial parameters (rho and lambda), and Wald tests.

### Usage

```
## S3 method for class 'summary.SARARgamlss'
print(x, ...)
```

### Arguments

| | |
|---|---|
| x | An object of class 'summary.SARARgamlss'. |
| ... | Additional arguments (currently unused). |

### Value

Print a summary for the specified GAMLSS model.

## ptfamily *Truncated Poisson Family for GLM*

### Description

This function defines a truncated Poisson family for use in Generalized Linear Models (GLMs), where zero values are not allowed. It modifies the Poisson likelihood by excluding zero-count observations.

### Usage

```
ptfamily(link = "log")
```

### Arguments

| | |
|---|---|
| link | Character string or a link-glm object specifying the link function. Accepted values are "log", "identity", and "sqrt". |

### Value

An object of class "family" that can be used in `glm()`.

## Examples

```
set.seed(123)
y <- rpois(100, lambda = 3)
y <- y[y > 0]  # Truncate zeros
x <- rnorm(length(y))
model <- glm(y ~ x, family = ptfamily())
summary(model)
```

---

SARARgamlss *SARARgamlss: Spatial Autoregressive Generalized Additive Model for Location Scale (GAMLSS)*

---

## Description

This function estimates a Spatial Autoregressive Generalized Additive Model for Location Scale (SARARgamlss) using GAMLSS. The model includes both spatial dependencies and the possibility of non-parametric terms in the formulas for the mean and variance. The function supports SAR, SARAR, and SEM model types and performs the estimation through an iterative process that updates spatial dependence parameters. The variance of the spatial parameters $\hat{\rho}$ and $\hat{\lambda}$ is estimated using the inverse of the Hessian matrix from the optimization.

## Usage

```
SARARgamlss(
  formula,
  sigma.formula = ~1,
  W1 = diag(0, nrow(data)),
  W2 = diag(0, nrow(data)),
  data,
  tol = 1e-04,
  maxiter = 20,
  type = c("SAR", "SARAR", "SEM"),
  weights = NULL
)
```

## Arguments

| | |
|---|---|
| formula | A formula specifying the mean structure of the model (response ~ explanatory variables). |
| sigma.formula | A formula specifying the variance structure of the model (default: ~1). |
| W1 | A spatial weights matrix for the SAR term (default: identity matrix). |
| W2 | A spatial weights matrix for the SARAR term (default: identity matrix). |
| data | A data.frame containing the variables used in the model. |
| tol | Convergence tolerance (default: 1E-4). |

| | |
|---|---|
| maxiter | Maximum number of iterations for optimization (default: 20). |
| type | The type of spatial model to fit: one of "SAR", "SARAR", or "SEM". |
| weights | Optional weights for the observations (default: NULL). |

## Value

A fitted GAMLSS model object with spatial autoregressive terms. The model object also includes the variance of the spatial parameters $\hat{\rho}$ and $\hat{\lambda}$

## References

Toloza-Delgado, J. D., Melo, O. O., & Cruz, N. A. Joint spatial modeling of mean and non-homogeneous variance combining semiparametric SAR and GAMLSS models for hedonic prices. Spatial Statistics, 65, 100864 (2025) @source https://doi.org/10.1016/j.spasta.2024.100864

## Examples

```
library(spdep)
library(gamlss)
data(oldcol)
# Create spatial weight matrices W1 and W2
W1 <- spdep::nb2mat(COL.nb, style = "W")
W2 <- W1  # In this case, assume the same spatial weights for both
# Fit a SARARgamlss model
result <- SARARgamlss(formula = CRIME ~ INC + cs(HOVAL),
sigma.formula = ~ INC + pb(HOVAL), W1 = W1, W2 = W2,data = COL.OLD,
tol = 1E-4,  maxiter = 20, type = "SARAR")
summary_SAR(result)
gamlss::term.plot(result$gamlss, what="mu")
```

---

# summary_SAR *Custom Summary Function for SARARgamlss and GEESAR Models*

---

## Description

This function generates a summary for objects of class 'SARARgamlss' or 'GEESAR'. It combines the summary outputs for both models, including GAMLSS model details, spatial parameters (rho and lambda), and Wald tests.

## Usage

```
summary_SAR(object)
```

## Arguments

| | |
|---|---|
| object | An object of class 'SARARgamlss' or 'GEESAR'. |

## Value

A list containing the summary for the specified model class.

## Examples

```
library(spdep)
library(gamlss)
data(oldcol)
W1 <- spdep::nb2mat(COL.nb, style = "W")
W2 <- W1  # In this case, assume the same spatial weights for both
# Fit a SARARgamlss model
result_sarar <- SARARgamlss(formula = CRIME ~ INC + HOVAL,
                            sigma.formula = ~ INC + pb(HOVAL),
                            W1 = W1, W2 = W2, data = COL.OLD,
                            type="SAR")
summary_SAR(result_sarar)

# Example for GEESAR model
result_geesar <- GEESAR(formula = CRIME ~ INC + HOVAL, data = COL.OLD, W = W1)
summary_SAR(result_geesar)
```

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