

Package ‘rsae’

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Type Package

Title Robust Small Area Estimation

Version 0.2

Description Empirical best linear unbiased prediction (EBLUP) and robust prediction of the area-level means under the basic unit-level model. The model can be fitted by maximum likelihood or a (robust) M-estimator. Mean square prediction error is computed by a parametric bootstrap.

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BugReports <https://github.com/tobiasschoch/rsae/issues>

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rsae-package	<i>Robust Small Area Estimation</i>
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Description

The package implements methods to fit the basic unit-level model (also known as model type "B" in Rao, 2003, or nested-error regression model in Battese et al., 1988), to predict area-specific means by the empirical best linear unbiased predictor (EBLUP) or a robust prediction method (Copt and Victoria-Feser, 2009; Heritier et al., 2011), and to compute the mean square prediction error of the predicted area-level means by a parametric bootstrap (Sinha and Rao, 2009; see also Hall and Maiti, 2006; Lahiri, 2003).

The methods are discussed in Schoch (2012).

Details

Implemented methods:

- maximum likelihood estimator
- Huber-type M-estimator (RML II of Richardson and Welsh, 1995, not the method proposed in Sinha and Rao, 2009); see Schoch (2012) for details

How to: Data analysis involves the following steps:

1. prepare the data/ specify the model for estimation; see `saemodel()`
2. fit the model by various (robust) methods; see `fitsaemodel()`
3. (robustly) predict the random effects and the area means; see `robpredict()`

References

- Battese, G. E., Harter, R. M., and W.A. Fuller (1988). An error component model for prediction of county crop areas using. *Journal of the American Statistical Association* **83**, 28–36. doi:10.2307/2288915
- Copt, S. and M.-P. Victoria-Feser (2009). *Robust Predictions in Mixed Linear Models*, Research Report, University of Geneva.
- Lahiri, P. (2003). On the impact of bootstrap in survey sampling and small area estimation. *Statistical Science* **18**, 199–210. doi:10.1214/ss/1063994975
- Hall, P. and T. Maiti (2006). On parametric bootstrap methods for small area prediction. *Journal of the Royal Statistical Society. Series B* **68**, 221–238. doi:10.1111/j.14679868.2006.00541.x
- Heritier, S., Cantoni, E., Copt, S., and M.-P. Victoria-Feser (2009). *Robust methods in Biostatistics*, New York: John Wiley and Sons.

- Rao, J.N.K. (2003). *Small Area Estimation*, New York: John Wiley and Sons.
- Richardson, A.M. and A.H. Welsh (1995). Robust restricted maximum likelihood in mixed linear model. *Biometrics* **51**, 1429–1439. doi:10.2307/2533273
- Schoch, T. (2012). Robust Unit-Level Small Area Estimation: A Fast Algorithm for Large Datasets. *Austrian Journal of Statistics* **41**, 243–265. <http://www.stat.tugraz.at/AJS/ausg124/124Schoch.pdf>
- Sinha, S.K. and J.N.K. Rao (2009). Robust small area estimation. *Canadian Journal of Statistics* **37**, 381–399. doi:10.1002/cjs.10029

fitsaemodel

Fitting SAE Models

Description

`fitsaemodel` fits SAE models that have been specified by `saemodel()` (or synthetic data generated by `makedata()`) for various (robust) estimation methods.

Usage

```
fitsaemodel(method, model, ...)
convergence(object)

## S3 method for class 'fit_model_b'
print(x, digits = max(3L, getOption("digits") - 3L),
      ...)
## S3 method for class 'summary_fit_model_b'
print(x, digits = max(3L, getOption("digits")
  - 3L), ...)
## S3 method for class 'fit_model_b'
summary(object, ...)
## S3 method for class 'fit_model_b'
coef(object, type = "both", ...)
```

Arguments

<code>method</code>	[character] estimation method; <code>method = "ml"</code> for (non-robust) maximum likelihood or <code>method = "huberm"</code> for Huber-type M-estimation.
<code>model</code>	an object of class "saemodel", i.e., a SAE model; see <code>saemodel()</code> .
<code>digits</code>	[integer] number of digits printed by the <code>print()</code> and <code>summary()</code> methods.
<code>object</code>	an object of class "fit_model_b".
<code>x</code>	an object of class "fit_model_b".
<code>type</code>	[character] name effects to be extracted by the <code>coef</code> method; it can take one of the following possibilities: "both" (extracts fixed and random effects; default), "ranef" (only random effects), or "fixef" (only fixed effects).
<code>...</code>	additional arguments passed on to <code>fitsaemodel.control()</code> .

Details

Function `fitsaemodel()` computes the following estimators:

- maximum likelihood (ML): `method = "ml"`,
- Huber-type M-estimation: `method = "huberm"`; this method is called RML II by Richardson and Welsh (1995); see Schoch (2012)

Maximum likelihood: The ML is **not** robust against outliers.

Huber-type M-estimation: The call for the Huber-type M-estimator (with Huber psi-function) is: `fitsaemodel(method = "huberm", model, k)`, where k is the robustness tuning constant of the Huber psi-function, $k \in (0, \infty]$.

By default, the computation of the M-estimator is initialized by a robust estimate that derives from a fixed-effects model (centered by the median instead of the mean); see Schoch (2012) for the details.

If the data are supposed to be heavily contaminated (**or if the default algorithm did not converge**), one may try to initialize the algorithm underlying `fitsaemodel()` by a high breakdown-point estimate. The package offers two initialization methods: **NOTE:** the **robustbase** package (Maechler et al., 2022) must be installed to use this functionality.

- `init = "lts"`: least trimmed squares (LTS) regression from **robustbase**; see `ltsReg()` and Rousseeuw and Van Driessen (2006),
- `init = "s"`: regression S-estimator from **robustbase**; see `lmrob()` and Maronna et al. (2019).

For small and medium size datasets, both methods are equivalent in terms of computation time. For large data, the S-estimator is considerably faster.

Implementation: The methods are computed by (nested) iteratively re-weighted least squares and Brent's zero-in method (Brent, 1973). The functions depend on the subroutines in BLAS (Blackford et al., 2002) and LAPACK (Anderson et al., 2000); see Schoch (2012).

Value

An instance of the class `"fitmodel"`

References

- Anderson, E., Bai, Z., Bischof, C., Blackford, L. S., Demmel, J., Dongarra, J., et al. (2000). *LAPACK users' guide* (3rd ed.). Philadelphia: Society for Industrial and Applied Mathematics (SIAM).
- Blackford, L.S., Petitet, A., Pozo, R., Remington, K., Whaley, R.C., Demmel, J., et al. (2002). An updated set of basic linear algebra subprograms (BLAS). *ACM Transactions on Mathematical Software* **28**, 135–151. doi:10.1145/567806.567807
- Brent, R.P. (1973). *Algorithms for minimization without derivatives*. Englewood Cliffs, NJ: Prentice-Hall.
- Maechler, M., Rousseeuw, P., Croux, C., Todorov, V., Ruckstuhl, A., Salibian-Barrera, M., Verbeke, T., Koller, M., Conceicao, E.L.T. and M. Anna di Palma (2022). **robustbase: Basic Robust Statistics R package version 0.95-0**. <https://CRAN.R-project.org/package=robustbase>

- Maronna, R.A., Martin, D., V.J. Yohai and M. Salibian-Barrera (2019): *Robust statistics: Theory and methods*. Chichester: John Wiley and Sons, 2nd ed.
- Richardson, A.M. and A.H. Welsh (1995). Robust restricted maximum likelihood in mixed linear model. *Biometrics* **51**, 1429–1439. doi:10.2307/2533273
- Rousseeuw, P. J. and K. Van Driessen (2006). Computing LTS regression for large data sets. *Data Mining and Knowledge Discovery* **12**, 29–45. doi:10.1007/s1061800500244
- Schoch, T. (2012). Robust Unit-Level Small Area Estimation: A Fast Algorithm for Large Datasets. *Austrian Journal of Statistics* **41**, 243–265. <http://www.stat.tugraz.at/AJS/ausg124/124Schoch.pdf>

See Also

[fitsaemodel.control\(\)](#)

Examples

```
# generate synthetic data
m <- makedata()

# Huber M-estimate with robustness tuning constant k = 2
m_fitted <- fitsaemodel("huberm", m, k = 2)
m_fitted

# summary of the fitted model
summary(m_fitted)
```

`fitsaemodel.control` *Tuning Parameters of fitsaemodel*

Description

This function is used to define global settings and parameters that are used by [fitsaemodel\(\)](#).

Usage

```
fitsaemodel.control(niter = 40, iter = c(200, 200), acc = 1e-05,
  dec = 0, decorr = 0, init = "default", k_Inf = 20000, ...)
```

Arguments

<code>niter</code>	[integer] the maximum number of outer-loop iterations (default: <code>niter = 40</code>).
<code>iter</code>	[integer] the maximum number of inner-loop iterations. It can be a vector of size 2. The first element of the vector refers to the estimation of the regression coefficients β ; the second element refers to the estimation of the variance of the unit-level errors, v ; the maximum number of iterations used to compute the ratio of variances, d , cannot be modified (default: <code>iter = c(200, 200)</code>).

acc	[numeric] numeric tolerance used in the termination rule of the iterative updating algorithms. It can be a vector of size 4. The positions 1:4 of the vector acc refer to 1: (overall) outer-loop, 2: regression coefficients, β , 3: variance component, v , 4: ratio of variances d ; default: acc = 1e-05.
dec	[integer] type of matrix square root (decomposition); dec = 0 for eigenvalue decomposition (default) or dec = 1 for Cholesky decomposition.
decorr	[integer] type of decorrelation of the residuals; decorr = 0: no robust decorrelation (default); decorr = 1: means are replaced by medians.
init	[character] method by which the main algorithm is initialized. By default, init = "default" the algorithm is initialized by a robust fixed-effects estimator; alternatively, (and provided that the robustbase package is installed) one may choose one of the high-breakdown-point initial estimators: "Its" (fast least-trimmed squares, LTS, regression) or "s" (regression S-estimator). For more details on the initialization methods, see documentation of fitsaemodel() .
k_Inf	[numeric] tuning constant of the robust estimator that represents infinity (default: k_Inf = 20000).
...	additional arguments (not used).

Details

Changing the default values of the parameters may result in failure of convergence or loss of convergence speed.

Value

A list with entries

- niter
- iter
- acc
- k_Inf
- init
- dec
- decorr
- add

See Also

[fitsaemodel\(\)](#)

landsat	<i>LANDSAT Data: Prediction of County Crop Areas Using Survey and Satellite Data</i>
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Description

The landsat data is a compilation of survey and satellite data from Battese et al. (1988). It consists of data on segments (primary sampling unit; 1 segment approx. 250 hectares) under corn and soybeans for 12 counties in north-central Iowa.

Usage

```
data(landsat)
```

Format

A data frame with 37 observations on the following 10 variables.

SegmentsInCounty number of segments per county.

SegmentID sample segment identifier (per county).

HACorn hectares of corn for each sample segment (as reported in the June 1978 Enumerative Survey).

HASoybeans hectares of soybeans for each sample segment (as reported in the June 1978 Enumerative Survey).

PixelsCorn number of pixels classified as corn for each sample segment (LANDSAT readings).

PixelsSoybeans number of pixels classified as soybeans for each sample segment (LANDSAT readings).

MeanPixelsCorn county-specific mean number of pixels classified as corn.

MeanPixelsSoybeans county-specific mean number of pixels classified as soybeans.

outlier outlier indicator; observation number 33 is flagged as outlier.

CountyName county names (factor variable): Cerro Gordo, Hamilton, Worth, Humboldt, Franklin, Pocahontas, Winnebago, Wright, Webster, Hancock, Kossuth, Hardin.

Details

The landsat data in Battese et al. (1988) is a compilation of the LANDSAT satellite data from the U.S. Department of Agriculture (USDA) and the 1978 June Enumerative Survey.

Survey data: The survey data on the areas under corn and soybeans (reported in hectares) in the 37 segments of the 12 counties (north-central Iowa) have been determined by USDA Statistical Reporting Service staff, who interviewed farm operators. A segment is about 250 hectares.

Satellite data: For the LANDSAT satellite data, information is recorded as "pixels". A pixel is about 0.45 hectares. The USDA has been engaged in research toward transforming satellite information into good estimates of crop areas at the individual pixel and segments level. The satellite (LANDSAT) readings were obtained during August and September 1978.

Data for more than one sample segment are available for several counties (i.e., unbalanced data). Observations No. 33 has been flagged as outlier; see Battese et al. (1988, p. 28).

Source

The landsat data is from Table 1 of Battese et al. (1988, p. 29).

References

Battese, G. E., Harter, R. M., and W.A. Fuller (1988). An error component model for prediction of county crop areas using. *Journal of the American Statistical Association* **83**, 28–36. doi:[10.2307/2288915](https://doi.org/10.2307/2288915)

Examples

```
data(landsat)
```

makedata

Synthetic Data Generation for the Basic Unit-Level SAE Model

Description

This function generates synthetic data (possibly contaminated by outliers) for the basic unit-level SAE model.

Usage

```
makedata(seed = 1024, intercept = 1, beta = 1, n = 4, g = 20, areaID = NULL,
          ve = 1, ve.contam = 41, ve.epsilon = 0, vu = 1, vu.contam = 41,
          vu.epsilon = 0)
```

Arguments

seed	[integer] seed value used in <code>set.seed</code> (default seed = 1024).
intercept	[numeric] or [NULL] value of the intercept of the fixed-effects model or NULL for a model without intercept (default: intercept = 1).
beta	[numeric vector] value of the fixed-effect coefficients (without intercept; default: beta = 1). For each given coefficient, a vector of realizations is drawn from the standard normal distribution.
n	[integer] number of units per area in balanced-data setups (default: n = 4).
g	[integer] number of areas (default: g = 20).
areaID	[integer vector] or [NULL]. If one attempts to generate synthetic unbalanced data, one calls <code>makedata</code> with a vector, the elements of which area identifiers. This vector should contain a series of (integer valued) area IDs. The number of areas is set equal to the number unique IDs.
ve	[numeric] nonnegative value of model/ residual variance.

ve.contam	[numeric] nonnegative value of model variance of the outlier part in a mixture distribution (Tukey-Huber-type contamination model) $e = (1 - h)N(0, ve) + hN(0, ve.contam)$ $e = (1-h)*N(0, ve) + h*N(0, ve.contam)$.
ve.epsilon	[numeric] value in $[0, 1]$ that defines the relative number of outliers (i.e., epsilon or h in the contamination mixture distribution). Typically, it takes values between 0 and 0.5 (but it is not restricted to this interval).
vu	[numeric] value of the (area-level) random-effect variance.
vu.contam	[numeric] nonnegative value of the (area-level) random-effect variance of the outlier part in the contamination mixture distribution.
vu.epsilon	[numeric] value in $[0, 1]$ that defines the relative number of outliers in the contamination mixture distribution of the (area-level) random effects.

Details

Let y_i denote an area-specific n_i -vector of the response variable for the areas $i = 1, \dots, g$. Define a $(n_i \times p)$ -matrix X_i of realizations from the std. normal distribution, $N(0, 1)$, and let β denote a p -vector of regression coefficients. Now, the y_i are drawn using the law $y_i \sim N(X_i\beta, v_e I_i + v_u J_i)$ with v_e and v_u the variances of the model error and random-effect variance, respectively, and I_i and J_i denoting the identity matrix and matrix of ones, respectively.

In addition, we allow the distribution of the model/residual and area-level random effect to be contaminated (cf. Stahel and Welsh, 1997). Notably, the laws of $e_{i,j}$ and u_i are replaced by the Tukey-Huber contamination mixture:

- $e_{i,j} \sim (1 - \epsilon^{ve})N(0, v_e) + \epsilon^{ve}N(0, v_e^\epsilon)$
- $u_i \sim (1 - \epsilon^{vu})N(0, v_u) + \epsilon^{vu}N(0, v_u^\epsilon)$

where ϵ^{ve} and ϵ^{vu} regulate the degree of contamination; v_e^ϵ and v_u^ϵ define the variance of the contamination part of the mixture distribution.

Four different contamination setups are possible:

- no contamination (i.e., ve.epsilon = vu.epsilon = 0),
- contaminated model error (i.e., ve.epsilon != 0 and vu.epsilon = 0),
- contaminated random effect (i.e., ve.epsilon = 0 and vu.epsilon != 0),
- both are contaminated (i.e., ve.epsilon != 0 and vu.epsilon != 0).

Value

An instance of the class saemodel.

References

- Schoch, T. (2012). Robust Unit-Level Small Area Estimation: A Fast Algorithm for Large Datasets. *Austrian Journal of Statistics* **41**, 243–265. <http://www.stat.tugraz.at/AJS/ausg124/124Schoch.pdf>
- Stahel, W. A. and A. Welsh (1997). Approaches to robust estimation in the simplest variance components model. *Journal of Statistical Planning and Inference* **57**, 295–319. doi:10.1016/S0378-3758(96)00050X

See Also

[saemodel\(\)](#), [fitsaemodel\(\)](#)

Examples

```
mymodel <- makedata()
```

robpredict	<i>Robust Prediction of Random Effects, Fixed Effects, and Area-Specific Means</i>
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Description

Function `robpredict()` predicts the area-level means by (1) the empirical best linear unbiased predictor (EBLUP) or (2) a robust prediction method which is due to Copt and Victoria-Feser (2009). In addition, the function computes the mean square prediction error (MSPE) of the predicted area-level means by a parametric bootstrap method.

Usage

```
robpredict(fit, areameans = NULL, k = NULL, reps = NULL, seed = 1024,
           progress_bar = TRUE)
```

```
## S3 method for class 'pred_model_b'
print(x, digits = max(3L, getOption("digits") - 3L),
      ...)
## S3 method for class 'pred_model_b'
plot(x, type = "e", sort = NULL, ...)
## S3 method for class 'pred_model_b'
residuals(object, ...)
```

Arguments

<code>fit</code>	an object of class <code>fit_model_b</code> ; a fitted SAE model.
<code>areameans</code>	[matrix] or [NULL] area-level means of dimension (g, p) , where g and p denote, respectively, the number of areas and number of fixed-effects terms in the regression model (incl. the intercept). By default, <code>areadata = NULL</code> which implies that the predictions are base on the data used in fitting the model (not new data).
<code>k</code>	[numeric] or [NULL] robustness tuning constant (of the Huber psi-function) for robust prediction. Note that k does not necessarily have to be the same as the k that has been used in <code>fitsaemodel()</code> . By default, <code>k = NULL</code> which implies that the tuning constant specified in <code>fitsaemodel()</code> is used.
<code>reps</code>	[integer] or [NULL] number of bootstrap replicates for the computation of the mean squared prediction error (MSPE). If <code>reps = NULL</code> the MSPE is not computed.

seed	[integer] a positive integer used as argument seed in <code>set.seed()</code> to specify the random seed.
progress_bar	[logical] whether a progress bar is displayed for the parametric bootstrap; see NOTE below.
x	an object of class "pred_model_b".
digits	[integer] number of digits to be printed by.
type	[character] type of plot method: "e" (error bars; default) or "l" (lines).
sort	[character] or [NULL] if sort = "means", the predicted means are plotted in ascending order (default: sort = NULL); similarly, with sort = "fixef" and sort = "ranef" the predicted means are sorted along the fixed effects or the random effects, respectively.
object	an object of class fit_model_b.
...	additional arguments (not used).

Details

Function `robpredict()` computes predictions of the area-level means and—if required—an estimate of the area-specific mean square prediction error (MSPE).

Prediction of area-level means • Case 1: If `areameans` is a matrix with area-level means of the explanatory variables, then the computation of the fixed effects effects are based on `areameans`.

- Case 2: If `areameans` = NULL, then the predictions are based on the sample data that have been used to fit the model.

Mean square prediction error • If `reps` = NULL, the number of bootstrap replicates is not specified; hence, MSPE is not computed.

- If `reps` is a positive integer and `areameans` is not NULL (see Case 1 above), then a (robust) parametric bootstrap estimate of MSPE is computed as proposed by Sinha and Rao (2009); see also Lahiri (2003) and Hall.

Robustness • The EBLUP obtains if `k` = NULL, i.e., if the robustness tuning constant `k` is unspecified.

- Robust predictions of the area-level means are computed if `k` is a nonnegative real number. Small values of `k` imply that outliers are heavily downweighted; formally, the EBLUP corresponds to choosing the tuning constant `k` equal to infinity. The value of the tuning constant `k` specified in `robpredict()` can be different from the tuning constant `k` used in fitting the model. The robust prediction method is due to Copt and Victoria-Feser (2009); see also Heritier et al. (2009, 113-114) and differs from the method in Sinha and Rao (2009).

Value

An instance of the S3 class `pred_model_b`

NOTE

Users of Rgui .exe on Windows are recommended to call `robpredict()` with argument `progress_bar = FALSE` because Rgui .exe does not handle calls to `txtProgressBar()` well (the execution time of the same job increases and it tends to stall the execution of R). Users of R-Studio and Rterm.exe are **not** affected.

References

- Copt, S. and M.-P. Victoria-Feser (2009). *Robust Predictions in Mixed Linear Models*, Research Report, University of Geneva.
- Lahiri, P. (2003). On the impact of bootstrap in survey sampling and small area estimation. *Statistical Science* **18**, 199–210. doi:[10.1214/ss/1063994975](https://doi.org/10.1214/ss/1063994975)
- Hall, P. and T. Maiti (2006). On parametric bootstrap methods for small area prediction. *Journal of the Royal Statistical Society. Series B* **68**, 221–238. doi:[10.1111/j.14679868.2006.00541.x](https://doi.org/10.1111/j.14679868.2006.00541.x)
- Heritier, S., Cantoni, E., Copt, S., and M.-P. Victoria-Feser (2009). *Robust methods in biostatistics*. New York: John Wiley and Sons.
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- Sinha, S.K. and J.N.K. Rao (2009). Robust small area estimation. *Canadian Journal of Statistics* **37**, 381–399. doi:[10.1002/cjs.10029](https://doi.org/10.1002/cjs.10029)

See Also

[saemodel\(\)](#), [makedata\(\)](#), [fitsaemodel\(\)](#)

Examples

```
# generate synthetic data
m <- makedata()

# Huber M-estimate with robustness tuning constant k = 2
m_fit <- fitsaemodel("huberm", m, k = 2)
m_fit

# summary of the fitted model
summary(m_fit)

# robust prediction of the random effects and the area-level means; here,
# we choose the robustness tuning constant k equal to 1.8
m_predicted <- robpredict(m_fit, k = 1.8)
m_predicted
```

saemodel

*Setting Up a SAE Model***Description**

Function `saemodel()` is used to specify a model. Once a model has been specified, it can be fitted using `fitsaemodel()` by different estimation methods.

Usage

```
saemodel(formula, area, data, type = "b", na.omit = FALSE)

## S3 method for class 'saemodel'
print(x, ...)
## S3 method for class 'saemodel'
summary(object, ...)
## S3 method for class 'saemodel'
as.matrix(x, ...)
```

Arguments

<code>formula</code>	a formula object of describing the fixed-effects part of the model, with the response on the RHS of the <code>~</code> operator and the terms or regressors, separated by <code>+</code> operators, on the LHS of the formula.
<code>area</code>	a one-sided formula object. A <code>~</code> operator followed by only one single term defining the area-specific random-effect part.
<code>data</code>	<code>data.frame</code> .
<code>type</code>	[character] "a" or "b" referring to J.N.K. Rao's definition of model type A (area-level model) or B (unit-level model); default is "b".
<code>na.omit</code>	[logical] indicating whether NA values should be removed before the computation proceeds. Note that none of the algorithms can cope with missing values.
<code>x</code>	an object of class "saemodel".
<code>object</code>	an object of the class "saemodel".
<code>...</code>	additional arguments (not used).

Details

Function `saemodel()` is used to specify a model.

- `model` is a symbolic description (formula) of the fixed-effects model to be fitted. A typical model has the form `response ~ terms` where `response` is the (numeric) response vector and `terms` is a series of terms which specifies a linear predictor for response (explanatory variables); see [formula](#). A formula has an implied intercept term. To remove this use either `y ~ x - 1` or `y ~ 0 + x`; see [formula](#) for more details of allowed formulae.

- `area` is a symbolic description (formula) of the random effects (nested error structure). It must be right-hand side only formula consisting of one term, e.g., `~ areaDefinition`.

The data must not contain missing values.

The design matrix (i.e., matrix of the explanatory variables defined the right-hand side of model) must have full column rank; otherwise execution is terminated by an error.

Once a model has been specified, it can be fitted by `fitsaemodel()`.

Value

An instance of the S3 class "saemodel"

References

Rao, J.N.K. (2003). *Small Area Estimation*, New York: John Wiley and Sons.

See Also

`makedata()`, `fitsaemodel()`

Examples

```
data("landsat")
model <- saemodel(formula = HACorn ~ PixelsCorn + PixelsSoybeans,
  area = ~CountyName,
  data = subset(landsat, subset = (outlier == FALSE)))
```

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