# Package ‘goric’

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**Type** Package  
**Title** Generalized Order-Restricted Information Criterion  
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**Maintainer** Daniel Gerhard <00gerhard@gmail.com>  
**Description** Generalized Order-Restricted Information Criterion (GORIC) value for a set of hypotheses in multivariate linear models and generalised linear models.

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### constrMat

**Generate Constraint Matrices**

**Description**

Generate a constraint matrix with a predefined structure

**Usage**

```r
constrMat(n, type = c("monotone", "control", "average", "laverage", "uaverage", "caverage"), base = 1)
```

**Arguments**

- `n`: a (possibly named) vector of sample sizes for each group
- `type`: character string defining the type of constraints; one of "monotone", "control", "average", "laverage", "uaverage", or "caverage"
- `base`: column of the constraint matrix representing a control group (when `type = "control"`)

**Value**

a constraint matrix

**See Also**

- `orlm`, `constrSet`

**Examples**

```r
n <- c(10, 20, 30, 40)
constrMat(n, type="monotone")
constrMat(n, type="control", base=2)
constrMat(n, type="average")
constrMat(n, type="laverage")
constrMat(n, type="uaverage")
constrMat(n, type="caverage", base=2)
```
**constrSet**  

Generate Constraint Sets

**Description**

Generate sets of constraint matrices (`constr`), right hand side elements, and numbers of equality constraints (`nec`) with a predefined structure.

**Usage**

```r
constrSet(n, set = c("sequence", "seqcontrol", "lplateau", "uplateau",  
                      "downturn", "williams"), direction = c("increase", "decrease"), base = 1)
```

**Arguments**

- `n`: a (possibly named) vector of sample sizes for each group.
- `set`: character string defining the type of constraints; one of "sequence", "seqcontrol", "lplateau", "uplateau", or "downturn".
- `direction`: direction of the inequality constraints, either "increase" or "decrease".
- `base`: column of the constraint matrix representing a control group.

**Value**

A list with slots `constr`, `rhs`, and `nec` for each constraint definition.

**See Also**

`orlm`, `constrMat`

**Examples**

```r
n <- c(10, 20, 30, 40)
constrSet(n, set = "sequence")
constrSet(n, set = "seqcontrol")
constrSet(n, set = "lplateau")
constrSet(n, set = "uplateau")
constrSet(n, set = "downturn")
constrSet(n, set = "williams")
```
Calculate GORIC

**Description**

The `goric` function calculates the order-restricted log likelihood, the penalty of the generalised order restricted information criterion (GORIC), the GORIC values, differences to the minimum GORIC value, and the GORIC weights for a set of hypotheses, where the penalty is based on `iter` iterations. The hypothesis with the lowest GORIC value is the preferred one. The GORIC weights reflect the support of each hypothesis in the set. To compare two hypotheses (and not one to the whole set), one should examine the ratio of the two corresponding GORIC weights. To safeguard for weak hypotheses (i.e., hypotheses not supported by the data), one should include a model with no constraints (the so-called unconstrained model).

**Usage**

```r
goric(object, ..., iter = 1e+05, type = "GORIC", dispersion = 1,
       mc.cores = 1)
```

### S3 method for class `orlm`

```r
goric(object, ..., iter = 1e+05, type = "GORIC",
       mc.cores = 1)
```

### S3 method for class `orgls`

```r
goric(object, ..., iter = 1e+05, type = "GORIC",
       mc.cores = 1)
```

### S3 method for class `list`

```r
goric(object, ..., iter = 1e+05, type = "GORIC",
       dispersion = 1, mc.cores = 1)
```

### S3 method for class `orglm`

```r
goric(object, ..., iter = 1e+05, type = "GORIC",
       dispersion = 1, mc.cores = 1)
```

**Arguments**

- `object`: an object of class orlm, orgls, orglm, or a list of these objects
- `...`: further objects of class orlm, orgls, or orglm
- `iter`: number of iterations to calculate GORIC penalty terms
- `type`: if "GORIC" (default), the penalty term for the generalized order restriction information criterion is computed; with "GORICCa" or "GORICCb" small sample corrections for the penalty term are applied
- `dispersion`: dispersion parameter to scale GORIC analogously to QAIC in generalized linear models
- `mc.cores`: number of cores using a socket cluster implemented in package parallel
Value

A data.frame with the information criteria or a single penalty term.

References


See Also

*orlm*, *orgls*

Examples

```r
# A Fortran 90 program for the generalization of the
# order restricted information criterion.
# constraint definition
cmat <- cbind(diag(3), 0) + cbind(0, -diag(3))
constr <- kronecker(diag(3), cmat)
constr

# no effect model
(fm0 <- orlm(cbind(SDH, SGOT, SGPT) ~ dose-1, data=vinylidene,
             constr=constr, rhs=rep(0, nrow(constr)), nec=nrow(constr)))

# order constrained model (increasing serum levels with increasing doses)
fm1 <- orlm(cbind(SDH, SGOT, SGPT) ~ dose-1, data=vinylidene,
             constr=constr, rhs=rep(0, nrow(constr)), nec=0)
summary(fm1)

# unconstrained model
(fmunc <- orlm(cbind(SDH, SGOT, SGPT) ~ dose-1, data=vinylidene,
               constr=matrix(0, nrow=1, ncol=12), rhs=0, nec=0))

# calculate GORIC
# (only small number of iterations to decrease computation time, default: iter=100000)
goric(fm0, fm1, fmunc, iter=1000)
```
goric_penalty

GORIC penalty term

Description
Calculates the GORIC penalty term (level probability) by Monte-Carlo simulation.

Usage
goric_penalty(object, iter = 1e+05, type = "GORIC", mc.cores = 1)
orglm_penalty(object, iter = 1e+05, type = "GORIC", mc.cores = 1)

Arguments
object an object of class orlm, orgls (or orglm for function orglm_penalty)
iter number of iterations to calculate GORIC penalty terms
type if "GORIC" (default), the penalty term for the generalized order restriction information criterion is computed; with "GORICCa" or "GORICCb" small sample corrections for the penalty term are applied
mc.cores number of cores using a socket cluster implemented in package parallel

See Also
orlm, orgls, orglm

orglm
Fitting Order-Restricted Generalised Linear Models

Description
orglm is used to fit generalised linear models with restrictions on the parameters, specified by giving a description of the linear predictor, a description of the error distribution, and a description of a matrix with linear constraints. The quadprog package is used to apply linear constraints on the parameter vector.

Usage
orglm(formula, family = gaussian, data, weights, subset, na.action,
      start = NULL, etastart, mustart, offset, control = list(...),
      model = TRUE, method = "orglm.fit", x = FALSE, y = TRUE,
      contrasts = NULL, constr, rhs, nec, ...)

orglm.fit(x, y, weights = rep(1, nobs), start = NULL, etastart = NULL,
         mustart = NULL, offset = rep(0, nobs), family = gaussian(),
         control = list(), intercept = TRUE, constr, rhs, nec)
Arguments

**formula**

an object of class "formula" (or one that can be coerced to that class): a symbolic description of the model to be fitted.

**family**

a description of the error distribution and link function to be used in the model. This can be a character string naming a family function, a family function or the result of a call to a family function. (See `family` for details of family functions.)

**data**

an optional data frame, list or environment (or object coercible by `as.data.frame` to a data frame) containing the variables in the model. If not found in data, the variables are taken from `environment(formula)`, typically the environment from which `orglm` is called.

**weights**

an optional vector of ‘prior weights’ to be used in the fitting process. Should be `NULL` or a numeric vector.

**subset**

an optional vector specifying a subset of observations to be used in the fitting process.

**na.action**

a function which indicates what should happen when the data contain NAs. The default is set by the `na.action` setting of `options`, and is `na.fail` if that is unset. The ‘factory-fresh’ default is `na.omit`. Another possible value is `NULL`, no action. Value `na.exclude` can be useful.

**start**

starting values for the parameters in the linear predictor.

**etastart**

starting values for the linear predictor.

**mustart**

starting values for the vector of means.

**offset**

this can be used to specify an *a priori* known component to be included in the linear predictor during fitting. This should be `NULL` or a numeric vector of length equal to the number of cases. One or more `offset` terms can be included in the formula instead or as well, and if more than one is specified their sum is used. See `model.offset`.

**control**

a list of parameters for controlling the fitting process. For `orglm` this is passed to `glm.control`.

**model**

a logical value indicating whether `model frame` should be included as a component of the returned value.

**method**

the method to be used in fitting the model. The default method "orglm.fit" uses iteratively reweighted least squares with a quadratic programming step included at each iteration.

**x**

is a design matrix of dimension n * p

**y**

is a vector of observations of length n.

**contrasts**

an optional list. See the `contrasts.arg` of `model.matrix.default`.

**constr**

a matrix with linear constraints. The columns of this matrix should correspond to the columns of the design matrix.

**rhs**

right hand side of the linear constraint formulation. A numeric vector with a length corresponding to the rows of `constr`.

**nec**

Number of equality constraints. The first `nec` constraints defined in `constr` are treated as equality constraints; the remaining ones are inequality constraints.
For \texttt{orglm}: arguments to be used to form the default control argument if it is not supplied directly.

intercept logical. Should an intercept be included in the \textit{null} model?

\textbf{Details}

Non-\texttt{NULL} weights can be used to indicate that different observations have different dispersions (with the values in \texttt{weights} being inversely proportional to the dispersions); or equivalently, when the elements of \texttt{weights} are positive integers $w_i$, that each response $y_i$ is the mean of $w_i$ unit-weight observations. For a binomial GLM prior weights are used to give the number of trials when the response is the proportion of successes: they would rarely be used for a Poisson GLM. If more than one of \texttt{etastart}, \texttt{start} and \texttt{mustart} is specified, the first in the list will be used. It is often advisable to supply starting values for a \texttt{quasi} family, and also for families with unusual links such as \texttt{gaussian("log")}. For the background to warning messages about ‘fitted probabilities numerically 0 or 1 occurred’ for binomial GLMs, see Venables & Ripley (2002, pp. 197–8).

\textbf{Value}

An object of class "\texttt{orglm}" is a list containing at least the following components:

\textbf{coefficients} a named vector of coefficients

\textbf{residuals} the \textit{working} residuals, that is the residuals in the final iteration of the IWLS fit. Since cases with zero weights are omitted, their working residuals are \texttt{NA}.

\textbf{fitted.values} the fitted mean values, obtained by transforming the linear predictors by the inverse of the link function.

\textbf{rank} the numeric rank of the fitted linear model.

\textbf{family} the \texttt{family} object used.

\textbf{linear.predictors} the linear fit on link scale.

\textbf{deviance} up to a constant, minus twice the maximized log-likelihood. Where sensible, the constant is chosen so that a saturated model has deviance zero.

\textbf{null.deviance} The deviance for the null model, comparable with \textbf{deviance}. The null model will include the offset, and an intercept if there is one in the model. Note that this will be incorrect if the link function depends on the data other than through the fitted mean: specify a zero offset to force a correct calculation.

\textbf{iter} the number of iterations of IWLS used.

\textbf{weights} the \textit{working} weights, that is the weights in the final iteration of the IWLS fit.

\textbf{prior.weights} the weights initially supplied, a vector of 1s if none were.

\textbf{df.residual} the residual degrees of freedom of the unconstrained model.

\textbf{df.null} the residual degrees of freedom for the null model.

\textbf{y} if requested (the default) the \texttt{y} vector used. (It is a vector even for a binomial model.)

\textbf{converged} logical. Was the IWLS algorithm judged to have converged?

\textbf{boundary} logical. Is the fitted value on the boundary of the attainable values?
Author(s)
Modification of the original glm.fit by Daniel Gerhard. The original R implementation of glm was written by Simon Davies working for Ross Ihaka at the University of Auckland, but has since been extensively re-written by members of the R Core team. The design was inspired by the S function of the same name described in Hastie & Pregibon (1992).

References


See Also
glm, solve.QP

orgls

Fitting generalized least squares regression models with order restrictions

Description

orgls is used to fit generalised least square models analogously to the function gls in package nlme but with order restrictions on the parameters.

Usage

orgls(formula, data, constr, rhs, nec, weights = NULL, correlation = NULL, control = orlmcontrol())

## S3 method for class 'formula'
orgls(formula, data, constr, rhs, nec, weights = NULL, correlation = NULL, control = orlmcontrol())

Arguments

- formula an object of class "formula" (or one that can be coerced to that class): a symbolic description of the model to be fitted.
- data an optional data frame, list or environment (or object coercible by as.data.frame to a data frame) containing the variables in the model. If not found in data, the variables are taken from environment(formula), typically the environment from which orgls is called.
constr  matrix with constraints; with rows as constraint definition, columns should be in line with the parameters of the model
rhs   vector of right hand side elements; \( \text{Constr} \theta \geq \text{rhs} \); number should equal the number of rows of the constr matrix
nec   number of equality constraints; a numeric value treating the first nec constr rows as equality constraints, or a logical vector with TRUE for equality- and FALSE for inequality constraints.
weights a varClasses object; more details are provided on the help pages in R package nlme
correlation a corClasses object; more details are provided on the help pages in R package nlme
control a list of control arguments; see orlmcontrol for details.

Details

The constraints in the hypothesis of interest are defined by constr, rhs, and nec. The first nec constraints are the equality constraints: \( \text{Constr}[1 : \text{nec}, 1 : \text{tk}] \theta = \text{rhs}[1 : \text{nec}] \); and the remaining ones are the inequality constraints: \( \text{Constr}[\text{nec} + 1 : \text{cm}, 1 : \text{tk}] \theta \geq \text{rhs}[\text{nec} + 1 : \text{cm}] \). Two requirements should be met:

1. The first nec constraints must be the equality constraints (i.e., \( \text{Constr}[1 : \text{nec}, 1 : \text{tk}] \theta = \text{rhs}[1 : \text{nec}] \)) and the remaining ones the inequality constraints (i.e., \( \text{Constr}[\text{nec} + 1 : \text{cm}, 1 : \text{tk}] \theta \geq \text{rhs}[\text{nec} + 1 : \text{cm}] \)).
2. When rhs is not zero, Constr should be of full rank (after discarding redundant restrictions).

Value

an object of class orgls

References


See Also

solve.QP, goric
Examples

```r
# generating example data
library(mvtnorm)
# group means
m <- c(0,5,5,7)
# compound symmetry structure of residuals
# (10 individuals per group, rho=0.7)
cormat <- kronecker(diag(length(m)*10), matrix(0.7, nrow=length(m), ncol=length(m)))
diag(cormat) <- 1
# different variances per group
sds <- rep(c(1,2,0.5,1), times=10*length(m))
sigma <- crossprod(diag(sds), crossprod(cormat, diag(sds)))
response <- as.vector(rmvnorm(1, rep(m, times=10*length(m)), sigma=sigma))
dat <- data.frame(response,
                   grp=rep(LETTERS[1:length(m)], times=10*length(m)),
                   ID=as.factor(rep(1:(10*length(m)), each=length(m))))
```

```r
## set of gls models:
# unconstrained model
m1 <- orgls(response ~ grp-1, data = dat,
             constr=rbind(c(0,0,0,0)), rhs=0, nec=0,
             weights=varIdent(form=~1|grp),
             correlation=corCompSymm(form=~1|ID))

# simple order
m2 <- orgls(response ~ grp-1, data = dat,
             constr=rbind(c(-1,1,0,0),c(0,-1,1,0),c(0,0,-1,1)), rhs=c(0,0,0), nec=0,
             weights=varIdent(form=~1|grp),
             correlation=corCompSymm(form=~1|ID))

# equality constraints
m3 <- orgls(response ~ grp-1, data = dat,
             constr=rbind(c(-1,1,0,0),c(0,-1,1,0),c(0,0,-1,1)), rhs=c(0,0,0), nec=3,
             weights=varIdent(form=~1|grp),
             correlation=corCompSymm(form=~1|ID))
```

### orglsSet

**Set of generalised least-squares models**

Fitting a specific set of generalised least-squares models with order restrictions.

**Usage**

```r
orglsSet(formula, data, weights = NULL, correlation = NULL, set, direction = "increase", n = NULL, base = 1, control = orlmcontrol())
```
orlm

Fitting multivariate regression models with order restrictions

This is a modification of the lm function, fitting (multivariate) linear models with order constraints on the model coefficients.

Usage

orlm(formula, data, constr, rhs, nec, control = orlmcontrol())

## S3 method for class 'formula'
orlm(formula, data, constr, rhs, nec, control = orlmcontrol())

Arguments

formula an object of class "formula" (or one that can be coerced to that class): a symbolic description of the model to be fitted.
data an optional data frame, list or environment (or object coercible by as.data.frame to a data frame) containing the variables in the model. If not found in data, the variables are taken from environment(formula), typically the environment from which lm is called.
weights a varClasses object; more details are provided on the help pages in R package nlme
correlation a corClasses object; more details are provided on the help pages in R package nlme
set either a character string (see constrSet), or a list with slots for constr, rhs, and nec similarly defined as in orlm
direction direction of the order constraints
n a (possibly named) vector of sample sizes for each group
base column of the constraint matrix representing a control group
control a list of control arguments; see orlmcontrol for details.

Details

This function is just a wrapper for repeated calls of orgls with different constraint definitions. Predefined lists with constraint-sets can be constructed with function constrSet.

Value

a list with orgls objects

See Also

orgls, constrSet, goric
Arguments

formula  an object of class "formula" (or one that can be coerced to that class): a symbolic description of the model to be fitted.

data    an optional data frame, list or environment (or object coercible by as.data.frame to a data frame) containing the variables in the model. If not found in data, the variables are taken from environment(formula), typically the environment from which lm is called.

constr  matrix with constraints; with rows as constraint definition, columns should be in line with the parameters of the model

rhs     vector of right hand side elements; Constr $\theta \geq rhs$; number should equal the number of rows of the constr matrix

nec     number of equality constraints; a numeric value treating the first nec constr rows as equality constraints, or a logical vector with TRUE for equality- and FALSE for inequality constraints.

control a list of control arguments; see orlmcontrol for details.

Details

The contraints in the hypothesis of interest are defined by Constr, rhs, and nec. The first nec constraints are the equality contraints: $Constr[1 : nec, 1 : tk] \theta = rhs[1 : nec]$; and the remaining ones are the inequality contraints: $Constr[nec + 1 : cm, 1 : tk] \theta \geq rhs[nec + 1 : cm]$. Two requirements should be met:

1. The first nec constraints must be the equality contraints (i.e., $Constr[1 : nec, 1 : tk] \theta = rhs[1 : nec]$) and the remaining ones the inequality contraints (i.e., $Constr[nec + 1 : cm, 1 : tk] \theta \geq rhs[nec + 1 : cm]$).

2. When rhs is not zero, Constr should be of full rank (after discarding redundant restrictions).

Value

an object of class orlm

References


See Also

solve.QP, goric
Examples

########################################################################
## Artificial example ##
########################################################################
n <- 10
m <- c(1,2,1,5)
nm <- length(m)
dat <- data.frame(grp=as.factor(rep(1:nn, each=n)),
                   y=rnorm(n*nm, rep(m, each=n), 1))

# unrestricted linear model
cm1 <- matrix(0, nrow=1, ncol=4)
fm1 <- orlm(y ~ grp-1, data=dat, constr=cm1, rhs=0, nec=0)

# order restriction (increasing means)
cm2 <- rbind(c(-1,1,0,0),
             c(0,-1,1,0),
             c(0,0,-1,1))
fm2 <- orlm(y ~ grp-1, data=dat, constr=cm2,
            rhs=rep(0,nrow(cm2)), nec=0)

# order restriction (increasing at least by delta=1)
fm3 <- orlm(y ~ grp-1, data=dat, constr=cm2,
            rhs=rep(1,nrow(cm2)), nec=0)

# larger than average of the neighboring first 2 parameters
cm4 <- rbind(c(-0.5,-0.5,1,0),
             c(0,-0.5,-0.5,1))
fm4 <- orlm(y ~ grp-1, data=dat, constr=cm4,
            rhs=rep(0,nrow(cm4)), nec=0)

# equality constraints (all parameters equal)
fm5 <- orlm(y ~ grp-1, data=dat, constr=cm2,
            rhs=rep(0,nrow(cm2)), nec=nrow(cm2))

# alternatively
fm5 <- orlm(y ~ grp-1, data=dat, constr=cm2,
            rhs=rep(0,nrow(cm2)), nec=c(TRUE,TRUE,TRUE))

# constraining the 1st and the 4th parameter
# to their true values, and the 2nd and 3rd between them
cm6 <- rbind(c(1,0,0,0),
             c(-1,1,0,0),
             c(0,-1,0,1),
             c(-1,0,1,0),
             c(0,0,-1,1),
             c(0,0,0,1))
fm6 <- orlm(y ~ grp-1, data=dat, constr=cm6,
            rhs=c(1,rep(0,4),5), nec=c(TRUE,rep(FALSE,4),TRUE))

########################################################################
## Example from Kuiper, R.M. and Hoijtink, H. (Unpublished). ##
## A Fortran 90 program for the generalization of the order restricted information criterion. ##

# constraint definition

cmat <- cbind(diag(3), 0) + cbind(0, -diag(3))
constr <- kronecker(diag(3), cmat)

# no effect model
(fm0 <- orlm(cbind(SDH, SGOT, SGPT) ~ dose-1, data=vinylidene,
             constr=constr, rhs=rep(0, nrow(constr)), nec=nrow(constr)))

# order constrained model (increasing serum levels with increasing doses)
fm1 <- orlm(cbind(SDH, SGOT, SGPT) ~ dose-1, data=vinylidene,
            constr=constr, rhs=rep(0, nrow(constr)), nec=0)
summary(fm1)

# unconstrained model
(fmunc <- orlm(cbind(SDH, SGOT, SGPT) ~ dose-1, data=vinylidene,
               constr=matrix(0, nrow=1, ncol=12), rhs=0, nec=0))

---

orlmcontrol

### Control arguments for the orlm function.

**Description**

A list with control arguments controlling the orlm function

**Usage**

orlmcontrol(maxiter = 10000, absval = 1e-04)

**Arguments**

- `maxiter`: maximum number of iterations
- `absval`: tolerance criterion for convergence

**Value**

A list with control arguments

**See Also**

orlm
orlmSet  

*Set of multivariate regression models*

**Description**

Fitting a specific set of multivariate regression models with order restrictions.

**Usage**

```r
orlmSet(formula, data, set, direction = "increase", n = NULL, base = 1,
         control = orlmcontrol())
```

**Arguments**

- **formula**: an object of class "formula" (or one that can be coerced to that class): a symbolic description of the model to be fitted.
- **data**: an optional data frame, list or environment (or object coercible by as.data.frame to a data frame) containing the variables in the model. If not found in data, the variables are taken from environment(formula), typically the environment from which lm is called.
- **set**: either a character string (see constrSet), or a list with slots for constr, rhs, and nec similarly defined as in orlm
- **direction**: direction of the order constraints
- **n**: a (possibly named) vector of sample sizes for each group
- **base**: column of the constraint matrix representing a control group
- **control**: a list of control arguments; see orlmcontrol for details.

**Details**

This function is just a wrapper for repeated calls of orlm with different constraint definitions. Pre-defined lists with constraint-sets can be constructed with function constrSet.

**Value**

a list with orlm objects

**See Also**

orlm, constrSet, goric
Examples

# Artificial example#

```r
n <- 10
m <- c(1,2,4,5,2,1)
nm <- length(m)
dat <- data.frame(grp=as.factor(rep(1:nm, each=n)), y=rnorm(n*nm, rep(m, each=n), 1))
(cs <- constrSet(table(dat$grp), set="sequence"))
(oss <- orlmSet(y ~ grp-1, data=dat, set=cs))

# the same as:
oss <- orlmSet(y ~ grp-1, data=dat, set="sequence")
```

---

**Description**

Simulation function for orlm and orgls objects

**Usage**

```r
sim(object, n.sims)
```

## S3 method for class 'orlm'

```r
sim(object, n.sims)
```

## S3 method for class 'orgls'

```r
sim(object, n.sims)
```

**Arguments**

- `object` an object of class "orlm" or "orgls".
- `n.sims` number of simulation replications.

**Details**

Given the estimated coefficients of a orlm or orgls model, a set new parameters are generated. n.sims new sets of observations are generated based on the unrestricted model; these new datasets are used to estimate a new set of model coefficients incorporating the given order restrictions.

**Value**

a list with sets of simulated parameters.
See Also

orlm, orgls

Examples

### Artificial example ###

```r
n <- 10
m <- c(1,1,2)
dat <- data.frame(grp=as.factor(rep(1:length(m), each=n)),
                  y=rnorm(n*length(m), rep(m, each=n), 1))
cm <- rbind(c(-1,1,0),
            c(0,-1,1))
fm <- orlm(y ~ grp-1, data=dat, constr=cm, rhs=rep(0,nrow(cm)), nec=0)
b <- sim(fm, n.sims=1000)$coef
pairs(t(b), cex=0.3)
```

Description

Real data which are available on page 10 of Silvapulle and Sen (2005) and in a report prepared by Litton Bionetics Inc in 1984. These data were used in an experiment to find out whether vinylidene fluoride gives rise to liver damage. Since increased levels of serum enzyme are inherent in liver damage, the focus is on whether enzyme levels are affected by vinylidene fluoride. The variable of interest is the serum enzyme level. Three types of enzymes are inspected, namely SDH, SGOT, and SGPT. To study whether vinylidene fluoride has an influence on the three serum enzymes, four dosages of this substance are examined. In each of these four treatment groups, ten male Fischer-344 rats received the substance.

Usage

```
vinylidene
```

Format

A data frame with 40 observations on the following 4 variables.

```
  SDH  serum enzyme level of enzyme type SDH.
  SGOT serum enzyme level of enzyme type SGOT.
  SGPT serum enzyme level of enzyme type SGPT.
  dose factor with 4 levels (d1-d4) representing the 4 vinylidene fluoride concentrations.
```

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