Package 'dae'

February 13, 2024

Version 3.2.22

Date 2024-02-13

Title Functions Useful in the Design and ANOVA of Experiments

Depends R (>= 3.5.0), ggplot2

Imports ggpubr, graphics, methods, plyr, stats

Suggests testthat, vdiffr, R.rsp

VignetteBuilder R.rsp

Description The content falls into the following groupings: (i) Data, (ii) Factor manipulation functions, (iii) Design functions, (iv) ANOVA functions, (v) Matrix functions, (vi) Projector and canonical efficiency functions, and (vii) Miscellaneous functions. There is a vignette describing how to use the design functions for randomizing and assessing designs available as a vignette called 'DesignNotes'. The ANOVA functions facilitate the extraction of information when the 'Error' function has been used in the call to 'aov'. The package 'dae' can also be installed from <http://chris.brien.name/rpackages/>.

License GPL (>=2)

URL http://chris.brien.name

BugReports https://github.com/briencj/dae/issues

RoxygenNote 5.0.1

NeedsCompilation no

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R topics documented:

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dae-package *Functions Useful in the Design and ANOVA of Experiments*

Description

The content falls into the following groupings: (i) Data, (ii) Factor manipulation functions, (iii) Design functions, (iv) ANOVA functions, (v) Matrix functions, (vi) Projector and canonical efficiency functions, and (vii) Miscellaneous functions. There is a vignette describing how to use the design functions for randomizing and assessing designs available as a vignette called 'DesignNotes'. The ANOVA functions facilitate the extraction of information when the 'Error' function has been used in the call to 'aov'. The package 'dae' can also be installed from <http://chris.brien.name/rpackages/>.

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(i) Data

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SPLGrass.dat	Data for an experiment to investigate the effects of grazing patterns on pasture composition

(ii) Factor manipulation functions

Forms a new or revised factor:

fac.combine	Combines several factors into one
fac.multinested	Creates several factors, one for each level of a nesting.fac

	and each of whose values are either generated within those of the level of nesting.fac or using the values of a nested.fac
fac.nested	Creates a factor, the nested factor, whose values are generated within those of a nesting factor
fac.recast	Recasts a factor by modifying the values in the factor vector and/or the levels attribute, possibly combining some levels into a single level.
fac.recode	Recodes factor 'levels' using possibly nonunique values in a vector. (May be deprecated in future.)
fac.uselogical	Forms a two-level factor from a logical object
mpone	Converts the first two levels of a factor into the numeric values -1 and +1

Forms multiple new factors:

fac.divide	Divides a factor into several separate factors
fac.gen	Generate all combinations of several factors and, optionally, replicate them
fac.genfactors	Generate all combinations of the levels of the supplied factors, without replication
fac.split	Splits a factor whose levels consist of several delimited strings into several factors.
fac.uncombine	Cleaves a single factor, each of whose levels has delimited strings, into several factors using the separated strings.

Operates on factors:

as.numfac	Convert a factor to a numeric vector
fac.match	Match, for each combination of a set of columns in 'x', the row that has the same combination in 'table'

(iii) Design functions

Designing experiments:

designLatinSqrSys	Generate a systematic plan for a Latin Square design.
designRandomize	Randomize allocated to recipient factors to produce a layout for an experiment. It supersedes `fac.layout`.
no.reps	Computes the number of replicates for an experiment
detect.diff	Computes the detectable difference for an experiment
power.exp	Computes the power for an experiment

Plotting designs:

blockboundaryPlot	This function plots a block boundary on a plot produced by 'designPlot'. It supersedes blockboundary.plot.
designBlocksGGPlot	Adds block boundaries to a plot produced by designGGPlot.
designGGPlot	Plots labels on a two-way grid of coloured cells using `ggplot2` to represent an experimental design.

designPlot	A graphical representation of an experimental design using labels stored in a matrix. It superseded design.plot.
designPlotlabels	Plots labels on a two-way grid using ggplot2.

Assessing designs:

designAmeasures	Calculates the A-optimality measures from the variance matrix for predictions.
designAnatomy	Given the layout for a design, obtain its anatomy via the canonical analysis of its projectors to show the confounding and aliasing inherent in the design.
designTwophaseAnatomies	Given the layout for a design and three structure formulae, obtain the anatomies for the (i) two-phase, (ii) first-phase, (iii) cross-phase, treatments, and (iv) combined-units designs.
marginality.pstructure	Extracts the marginality matrix from a pstructure.object
marginality.pstructure	Extracts a list containing the marginality matrices from a pcanon.object
print.aliasing	Prints an aliasing data.frame
summary.pcanon	Summarizes the anatomy of a design, being the decomposition of the sample space based on its canonical analysis.

(iv) ANOVA functions

fitted.aovlist	Extract the fitted values for a fitted model from an aovlist object
fitted.errors	Extract the fitted values for a fitted model
interaction.ABC.plot	Plots an interaction plot for three factors
qqyeffects	Half or full normal plot of Yates effects
resid.errors	Extract the residuals for a fitted model
residuals.aovlist	Extract the residuals from an aovlist object
strength	Generate paper strength values
tukey.1df	Performs Tukey's one-degree-of-freedom-test-for-nonadditivity
yates.effects	Extract Yates effects

(v) Matrix functions

Operates on matrices:

elements	Extract the elements of an array specified by the subscripts
mat.dirprod	Forms the direct product of two matrices
mat.dirsum	Forms the direct sum of a list of matrices
mat.ginv	Computes the generalized inverse of a matrix
Zncsspline	Forms the design matrix for fitting the random effects for a natural cubic smoothing spline.

Compute variance matrices for supplied variance component values:

mat.random	Calculates the variance matrix for the random effects from a mixed model, based on a formula or a supplied matrix
mat.Vpred	Forms the variance matrix of predictions based on supplied matrices
mat.Vpredicts	Forms the variance matrix of predictions, based on supplied matrices or formulae.

Forms matrices using factors stored in a data.frame:

fac.ar1mat	Forms the ar1 correlation matrix for a (generalized) factor
fac.sumop	Computes the summation matrix that produces sums corresponding to a (generalized) factor
fac.vcmat	Forms the variance matrix for the variance component of a (generalized) factor

Forms patterned matrices:

mat.I	Forms a unit matrix
mat.J	Forms a square matrix of ones
mat.ncssvar	Forms a variance matrix for random cubic smoothing spline effects

Forms correlation matrices:

mat.cor	Forms a correlation matrix in which all correlations have the same value
mat.corg	Forms a general correlation matrix in which all correlations have different values
mat.ar1	Forms an ar1 correlation matrix
mat.ar2	Forms an ar2 correlation matrix
mat.ar3	Forms an ar3 correlation matrix
mat.arma	Forms an arma correlation matrix
mat.banded	Forms a banded matrix
mat.exp	Forms an exponential correlation matrix
mat.gau	Forms a gaussian correlation matrix
mat.ma1	Forms an ma1 correlation matrix
mat.ma2	Forms an ma2 correlation matrix
mat.sar	Forms an sar correlation matrix
mat.sar2	Forms an sar2 correlation matrix

(vi) Projector and canonical efficiency functions

Projector class:

projector	Create projectors

projector-class	Class projector
is.projector	Tests whether an object is a valid object of class projector
print.projector	Print projectors
correct.degfree	Check the degrees of freedom in an object of class projector
degfree	Degrees of freedom extraction and replacement

Accepts two or more formulae:

designAnatomy	An anatomy of a design, obtained from a canonical analysis of the relationships between sets of projectors.
summary.pcanon	Summarizes the anatomy of a design, being the decomposition of the sample space based on its canonical analysis
print.summary.pcanon	Prints the values in an 'summary.pcanon' object
efficiencies.pcanon	Extracts the canonical efficiency factors from a list of class 'pcanon'

Accepts exactly two formulae:

projs.2canon	A canonical analysis of the relationships between two sets of projectors
projs.combine.p2canon	Extract, from a p2canon object, the projectors
summary.p2canon	A summary of the results of an analysis of the relationships between two sets of projectors
print.summary.p2canon	Prints the values in an 'summary.p2canon' object that give the combined decomposition
efficiencies.p2canon	Extracts the canonical efficiency factors from a list of class 'p2canon'

Accepts a single formula:

as.data.frame.pstructure	Coerces a pstructure.object to a data.frame
print.pstructure	Prints a pstructure.object
pstructure.formula	Takes a formula and constructs a pstructure.object that includes the orthogonalized projectors for the terms in a formula
porthogonalize.list	Takes a list of projectors and constructs a pstructure.object that includes projectors, each of which has been orthogonalized to all projectors preceding it in the list.

Others:

decomp.relate	Examines the relationship between the eigenvectors for two decompositions
efficiency.criteria	Computes efficiency criteria from a set of efficiency factors
fac.meanop	Computes the projection matrix that produces means
proj2.eigen	Canonical efficiency factors and eigenvectors in joint decomposition of two projectors

proj2.efficiency	Computes the canonical efficiency factors for the joint decomposition of two projectors
proj2.combine	Compute the projection and Residual operators for two, possibly nonorthogonal, projectors
show-methods	Methods for Function 'show' in Package dae

(vii) Miscellaneous functions

extab	Expands the values in table to a vector
get.daeTolerance	Gets the value of daeTolerance for the package dae
harmonic.mean	Calcuates the harmonic mean.
is.allzero	Tests whether all elements are approximately zero
rep.data.frame	Replicate the rows of a data.frame by repeating each row consecutively and/or repeating all rows as a group.
rmvnorm	Generates a vector of random values from a multivariate normal distribution
set.daeTolerance	Sets the value of daeTolerance for the package dae

Author(s)

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ABC.Interact.dat *Randomly generated set of values indexed by three factors*

Description

This data set has randomly generated values of the response variable MOE (Measure Of Effectiveness) which is indexed by the two-level factors A, B and C.

Usage

```
data(ABC.Interact.dat)
```

Format

A data.frame containing 8 observations of 4 variables.

Source

Generated by Chris Brien

`as.data.frame.pstructure` *Coerces a pstructure.object to a data.frame.*

Description

Coerces a `pstructure.object`, which is of class `pstructure`, to a `data.frame`. One can choose whether or not to include the `marginality` matrix in the data.frame. The `aliasing` component is excluded.

Usage

```
## S3 method for class 'pstructure'
as.data.frame(x, row.names = NULL, optional = FALSE, ...,
              omit.marginality = FALSE)
```

Arguments

`x`	The `pstructure.object`, which is of class `pstructure` and is to be coerced.
`row.names`	NULL or a `character` vector giving the row names for the data frame. Missing values are not allowed.
`optional`	A `logical` passed to `as.data.frame`. If TRUE, setting row names and converting column names (to syntactic names: see `make.names`) is optional. Note that all of R's base package `as.data.frame()` methods use `optional` only for column names treatment, basically with the meaning of `data.frame(*, check.names = !optional)`.
`...`	Further arguments passed to or from other methods.
`omit.marginality`	A `logical`, which, if `TRUE`, results in the `marginality` matrix being omitted from the `data.frame`.

Value

A `data.frame` with as many rows as there are non-aliased terms in the `pstructure.object`. The columns are `df`, `terms`, `sources` and, if `omit.marginality` is `FALSE`, the columns of the generated `levels` with columns of the `marginality` matrix that is stored in the `marginality` component of the object.

Author(s)

Chris Brien

See Also

`as.data.frame`.

Examples

```
## Generate a data.frame with 4 factors, each with three levels, in standard order
ABCD.lay <- fac.gen(list(A = 3, B = 3, C = 3, D = 3))

## create a pstructure object based on the formula ((A*B)/C)*D
ABCD.struct <- pstructure.formula(~ ((A*B)/C)*D, data =ABCD.lay)

## print the object either using the Method function or the generic function
ABCS.dat <- as.data.frame.pstructure(ABCD.struct)
as.data.frame(ABCD.struct)
```

`as.numfac` *Convert a factor to a numeric vector*

Description

Converts a `factor` to a numeric `vector` with approximately the numeric values of its `levels`. Hence, the `levels` of the `factor` must be numeric values, stored as characters. It uses the method described in `factor`. Use `as.numeric` to convert a `factor` to a numeric `vector` with integers 1, 2, ... corresponding to the positions in the list of levels. You can also use `fac.recast` to recode the levels to numeric values. If a `numeric` is supplied, it is left unchanged.

Usage

```
as.numfac(factor)
```

Arguments

`factor`	The `factor` to be converted.

Value

A numeric `vector`. An `NA` will be stored for any value of the factor whose level is not a number.

Author(s)

Chris Brien

See Also

`as.numeric`, `fac.recast` in package **dae**, `factor`.

Examples

```
## set up a factor and convert it to a numeric vector
a <- factor(rep(1:3, 4))
x <- as.numfac(a)
```

BIBDWheat.dat *Data for a balanced incomplete block experiment*

Description

The data set comes from Joshi (1987) and is the data from an experiment to investigate six varieties of wheat that employs a balanced incomplete block design (BIBD) with ten blocks, each consisting of three plots. For more details see the vignette accessed via `vignette("DesignNotes", package="dae")`.

Usage

```
data(BIBDWheat.dat)
```

Format

A data.frame containing 30 observations of 4 variables.

Source

Joshi, D. D. (1987) *Linear Estimation and Design of Experiments*. Wiley Eastern, New Delhi.

blockboundaryPlot *This function plots a block boundary on a plot produced by* designPlot.

Description

This function plots a block boundary on a plot produced by designPlot. It allows control of the starting unit, through rstart and cstart, and the number of rows (nrows) and columns (ncolumns) from the starting unit that the blocks to be plotted are to cover.

Usage

```
blockboundaryPlot(blockdefinition = NULL, blocksequence = FALSE,
                  rstart= 0, cstart = 0, nrows, ncolumns,
                  blocklinecolour = 1, blocklinewidth = 2)
```

Arguments

`blockdefinition`

A matrix of block sizes:

- if there is only one row, then the first element is interpreted as the no. rows in each block and blocks with this number of rows are to be repeated across the rows of the design.
- if there is more than one row, then each row of the matrix specifies a block, with the sequence of rows in the matrix specifying a corresponding sequence of blocks down the rows of the design.

Similarly, a single value for a column specifies a repetition of blocks of that size across the columns of the design, while several column values specifies a sequence of blocks across the columns of the size specified.

`blocksequence` A `logical` that determines whether block numbers are repetitions or sequences of block numbers.

`rstart` A `numeric` speccifying the row after which the plotting of block boundaries is to start.

`cstart` A `numeric` speccifying the column after which the plotting of block boundaries is to start.

`nrows` A `numeric` the number of rows (nrows), from the starting unit, that the blocks to be plotted are to cover.

`ncolumns` A `numeric` the number of columns (ncolumns), from the starting unit, that the blocks to be plotted are to cover.

`blocklinecolour`

A `character` string specifying the colour of the block boundary.

See `Colour specification` under the `par` function.

`blocklinewidth` A `numeric` giving the width of the block boundary to be plotted.

Value

no values are returned, but modifications are made to the currently active plot.

Author(s)

Chris Brien

See Also

`designPlot`, `par`, `DiGGer`

Examples

```
## Not run:
    SPL.Lines.mat <- matrix(as.numfac(Lines), ncol=16, byrow=T)
    colnames(SPL.Lines.mat) <- 1:16
    rownames(SPL.Lines.mat) <- 1:10
    SPL.Lines.mat <- SPL.Lines.mat[10:1, 1:16]
    designPlot(SPL.Lines.mat, labels=1:10, new=TRUE,
               rtitle="Rows",ctitle="Columns",
               chardivisor=3, rcellpropn = 1, ccellpropn=1,
               plotcellboundary = TRUE)
    #Plot Mainplot boundaries
    blockboundaryPlot(blockdefinition = cbind(4,16), rstart = 1,
                      blocklinewidth = 3, blockcolour = "green",
                      nrows = 9, ncolumns = 16)
    blockboundaryPlot(blockdefinition = cbind(1,4),
                      blocklinewidth = 3, blockcolour = "green",
                      nrows = 1, ncolumns = 16)
   blockboundaryPlot(blockdefinition = cbind(1,4), rstart= 9, nrows = 10, ncolumns = 16,
                      blocklinewidth = 3, blockcolour = "green")
    #Plot all 4 block boundaries
    blockboundaryPlot(blockdefinition = cbind(8,5,5,4), blocksequence=T,
                      cstart = 1, rstart= 1, nrows = 9, ncolumns = 15,
```

```
                    blocklinewidth = 3,blockcolour = "blue")
  blockboundaryPlot(blockdefinition = cbind(10,16), blocklinewidth=3, blockcolour="blue",
                    nrows=10, ncolumns=16)
   #Plot border and internal block boundaries only
   blockboundaryPlot(blockdefinition = cbind(8,14), cstart = 1, rstart= 1,
                    nrows = 9, ncolumns =  15,
                    blocklinewidth = 3, blockcolour = "blue")
   blockboundaryPlot(blockdefinition = cbind(10,16),
                    blocklinewidth = 3, blockcolour = "blue",
                    nrows = 10, ncolumns = 16)
## End(Not run)
```

`Cabinet1.des` *A design for one of the growth cabinets in an experiment with 50 lines and 4 harvests*

Description

The systematic design for a lattice square for 49 treatments consisting of four 7 x 7 squares. For more details see the vignette *daeDesignNotes.pdf*.

Usage

```
data(Cabinet1.des)
```

Format

A data.frame containing 160 observations of 15 variables.

`Casuarina.dat` *Data for an experiment with rows and columns from Williams (2002)*

Description

Williams (2002, p.144) provides an example of a resolved, Latinized, row-column design with four rectangles (blocks) each of six rows by ten columns. The experiment investigated differences between 60 provenances of a species of Casuarina tree, these provenances coming from 18 countries; the trees were inoculated prior to planting at two different times, time of inoculation being assigned to the four replicates so that each occurred in two replicates. At 30 months, diameter at breast height (Dbh) was measured. For more details see the vignette accessed via `vignette("DesignNotes", package="dae")`.

Usage

```
data(Casuarina.dat)
```

Format

A data.frame containing 240 observations of 7 variables.

Source

Williams, E. R., Matheson, A. C. and Harwood, C. E. (2002) *Experimental design and analysis for tree improvement*. 2nd edition. CSIRO, Melbourne, Australia.

`correct.degfree` *Check the degrees of freedom in an object of class projector*

Description

Check the degrees of freedom in an object of class "projector".

Usage

```
correct.degfree(object)
```

Arguments

`object`	An object of class "projector" whose degrees of freedom are to be checked.

Details

The degrees of freedom of the projector are obtained as its number of nonzero eigenvalues. An eigenvalue is regarded as zero if it is less than `daeTolerance`, which is initially set to.Machine$double.eps ^ 0.5 (about 1.5E-08). The function `set.daeTolerance` can be used to change `daeTolerance`.

Value

TRUE or FALSE depending on whether the correct degrees of freedom have been stored in the object of class "projector".

Author(s)

Chris Brien

See Also

`degfree`, `projector` in package **dae**.

`projector` for further information about this class.

Examples

```
## set up a 2 x 2 mean operator that takes the mean of a vector of 2 values
m <- matrix(rep(0.5,4), nrow=2)

## create a projector based on the matrix m
proj.m <- new("projector", data=m)

## add its degrees of freedom
degfree(proj.m) <- 1

## check degrees of freedom are correct
correct.degfree(proj.m)
```

dae-deprecated *Deprecated Functions in Package dae*

Description

These functions have been renamed and deprecated in dae.

Usage

```
Ameasures(...)
blockboundary.plot(...)
design.plot(...)
proj2.decomp(...)
proj2.ops(...)
projs.canon(...)
projs.structure(...)
```

Arguments

...	absorbs arguments passed from the old functions of the style foo.bar().

Author(s)

Chris Brien

daeTips *The intermittent, randomly-presented, startup tips.*

Description

The intermittent, randomly-presented, startup tips.

Startup tips

Need help? Enter help(package = 'dae') and click on 'User guides, package vignettes and other docs'.

Need help? The manual is in the doc subdirectory of the package's install directory.

Find out what has changed in dae: enter news(package = 'dae').

Need help to produce randomized designs? Enter vignette('DesignNotes', package = 'dae').

Need help to do the canonical analysis of a design? Enter vignette('DesignNotes', package = 'dae').
Use suppressPackageStartupMessages() to eliminate all package startup messages.

To see all the intermittent, randomly-presented, startup tips enter ?daeTips.

For versions between CRAN releases (and more) go to http://chris.brien.name/rpackages.

Author(s)

Chris Brien

`decomp.relate` *Examines the relationship between the eigenvectors for two decompositions*

Description

Two decompositions produced by `proj2.eigen` are compared by computing all pairs of crossproduct sums of eigenvectors from the two decompositions. It is most useful when the calls to `proj2.eigen` have the same Q1.

Usage

```
decomp.relate(decomp1, decomp2)
```

Arguments

`decomp1`	A `list` containing components efficiencies and eigenvectors such as is produced by `proj2.eigen`.
`decomp2`	Another `list` containing components efficiencies and eigenvectors such as is produced by `proj2.eigen`.

Details

Each element of the r1 x r2 `matrix` is the sum of crossproducts of a pair of eigenvectors, one from each of the two decompositions. A sum is regarded as zero if it is less than `daeTolerance`, which is initially set to .Machine$double.eps ^ 0.5 (about 1.5E-08). The function `set.daeTolerance` can be used to change `daeTolerance`.

Value

A `matrix` that is r1 x r2 where r1 and r2 are the numbers of efficiencies of `decomp1` and `decomp2`, respectively. The `rownames` and `columnnames` of the `matrix` are the values of the efficiency factors from `decomp1` and `decomp2`, respectively.

Author(s)

Chris Brien

See Also

`proj2.eigen`, `proj2.combine` in package **dae**, `eigen`.

Examples

```
## PBIBD(2) from p. 379 of Cochran and Cox (1957) Experimental Designs.
## 2nd edn Wiley, New York
PBIBD2.unit <- list(Block = 6, Unit = 4)
PBIBD2.nest <- list(Unit = "Block")
trt <- factor(c(1,4,2,5, 2,5,3,6, 3,6,1,4, 4,1,5,2, 5,2,6,3, 6,3,4,1))
PBIBD2.lay <- designRandomize(allocated = trt,
                              recipient = PBIBD2.unit,
                              nested.recipients = PBIBD2.nest)
```

```
##obtain sets of projectors
unit.struct <- pstructure(~ Block/Unit, data = PBIBD2.lay)
trt.struct <- pstructure(~ trt, data = PBIBD2.lay)

## obtain intra- and inter-block decompositions
decomp.inter <- proj2.eigen(unit.struct$Q["Block"], trt.struct$Q["trt"])
decomp.intra <- proj2.eigen(unit.struct$Q["Unit[Block]"], trt.struct$Q["trt"])

## check that intra- and inter-block decompositions are orthogonal
decomp.relate(decomp.intra, decomp.inter)
```

`degfree` *Degrees of freedom extraction and replacement*

Description

Extracts the degrees of freedom from or replaces them in an object of class "projector".

Usage

```
degfree(object)

degfree(object) <- value
```

Arguments

`object`	An object of class "projector" whose degrees of freedom are to be extracted or replaced.
`value`	An integer to which the degrees of freedom are to be set or an object of class "projector" or "matrix" from which the degrees of freedom are to be calulated.

Details

There is no checking of the correctness of the degrees of freedom, either already stored or as a supplied integer value. This can be done using `correct.degfree`.

When the degrees of freedom of the projector are to be calculated, they are obtained as the number of nonzero eigenvalues. An eigenvalue is regarded as zero if it is less than `daeTolerance`, which is initially set to `.Machine$double.eps ^ 0.5` (about 1.5E-08). The function `set.daeTolerance` can be used to change `daeTolerance`.

Value

An object of class "projector" that consists of a square, summetric, idempotent matrix and degrees of freedom (rank) of the matrix.

Author(s)

Chris Brien

See Also

`correct.degfree`, `projector` in package **dae**.

`projector` for further information about this class.

Examples

```
## set up a 2 x 2 mean operator that takes the mean of a vector of 2 values
m <- matrix(rep(0.5,4), nrow=2)

## coerce to a projector
proj.m <- projector(m)

## extract its degrees of freedom
degfree(proj.m)

## create a projector based on the matrix m
proj.m <- new("projector", data=m)

## add its degrees of freedom and print the projector
degfree(proj.m) <- proj.m
print(proj.m)
```

`designAmeasures` *Calculates the average variance of pairwise differences from the variance matrix for predictions*

Description

Calculates the average variance of pairwise differences between, or of elementary contrasts of, predictions using the variance matrix for the predictions. The weighted average variance of pairwise differences can be computed from a vector of `replications`, as described by Williams and Piepho (2015). It is possible to compute either A-optimality measure for different subgroups of the predictions. If groups are specified then the A-optimality measures are calculated for the differences between predictions within each group and for those between predictions from different groups. If groupsizes are specified, but groups are not, the predictions will be sequentially broken into groups of the size specified by the elements of groupsizes. The groups can be named.

Usage

```
designAmeasures(Vpred, replications = NULL, groupsizes = NULL, groups = NULL)
```

Arguments

`Vpred`	The variance `matrix` of the predictions. It can be obtained using `mat.Vpredicts`.
`replications`	A `numeric` vector whose length is equal to the number of rows (columns) in `Vpred` and whose elements are to be used to calculate weights for each pair of differences.
`groupsizes`	A `numeric` containing group sizes. The sum of the elements of `groupsizes` must be less than or equal to the order of `Vpred`. If `groupsizes` is a named `vector`, the names are used to label the groups. If `NULL`, either `groups` is used or the average for all pairwise differences is obtained.
`groups`	A `list`, each element of which is a `numeric`, vector with integers that specify the subroup of the predictions over whose pairwise differences the variances are to be averaged. If there is more than one group, the variances of all between and within group pairwise differences are averaged. If the elements of `groups` are named , the names are used to label the groups. If `groups` is `NULL`, either `groupsizes` is used or the average for all pairwise differences is obtained.

Details

The variance matrix of pairwise differences is calculated as $v_{ii}+v_{jj}-2v_{ij}$, where v_{ij} is the element from the ith row and jth column of `Vpred`. if `replication` is not `NULL` then weights are computed as $r_i * r_j/\text{mean}(\mathbf{r})$, where $\mathbf{r}$ is the `replication` vector and r_i and r_j are elements of $\mathbf{r}$. The (i, j) element of the variance matrix of pairwise differences is multiplied by the (i, j)th weight. Then the mean of the variances of the pairwise differences is computed for the nominated `groups`.

Value

A `matrix` containing the within and between group A-optimality measures.

Author(s)

Chris Brien

References

Smith, A. B., D. G. Butler, C. R. Cavanagh and B. R. Cullis (2015). Multi-phase variety trials using both composite and individual replicate samples: a model-based design approach. *Journal of Agricultural Science*, **153**, 1017-1029.

Williams, E. R., and Piepho, H.-P. (2015). Optimality and contrasts in block designs with unequal treatment replication. *Australian & New Zealand Journal of Statistics*, **57**, 203-209.

See Also

`mat.Vpred`, `designAnatomy`.

Examples

```
## Reduced example from Smith et al. (2015)
## Generate two-phase design
mill.fac <- fac.gen(list(Mrep = 2, Mday = 2, Mord = 3))
field.lay <- fac.gen(list(Frep = 2, Fplot = 4))
field.lay$Variety <- factor(c("D","E","Y","W","G","D","E","M"),
                            levels = c("Y","W","G","M","D","E"))
start.design <- cbind(mill.fac, field.lay[c(3,4,5,8,1,7,3,4,5,8,6,2),])
rownames(start.design) <- NULL

## Set up matrices
n <- nrow(start.design)
W <- model.matrix(~ -1+ Variety, start.design)
ng <- ncol(W)
Gg<- diag(1, ng)
Vu <- with(start.design, fac.vcmat(Mrep, 0.3) +
                         fac.vcmat(fac.combine(list(Mrep, Mday)), 0.2) +
                         fac.vcmat(Frep, 0.1) +
                         fac.vcmat(fac.combine(list(Frep, Fplot)), 0.2))
R <- diag(1, n)

## Calculate the variance matrix of the predicted random Variety effects
Vp <- mat.Vpred(W = W, Gg = Gg, Vu = Vu, R = R)

## Calculate A-optimality measure
designAmeasures(Vp)
designAmeasures(Vp, groups=list(fldUndup = c(1:4), fldDup = c(5,6)))
```

```
grpsizes <- c(4,2)
names(grpsizes) <- c("fldUndup", "fldDup")
designAmeasures(Vp, groupsizes = grpsizes)
designAmeasures(Vp, groupsizes = c(4))
designAmeasures(Vp, groups=list(c(1,4),c(5,6)))

## Calculate the variance matrix of the predicted fixed Variety effects, elminating the grand mean
Vp.reduc <- mat.Vpred(W = W, Gg = 0, Vu = Vu, R = R,
                      eliminate = projector(matrix(1, nrow = n, ncol = n)/n))
## Calculate A-optimality measure
designAmeasures(Vp.reduc)
```

`designAnatomy` *Given the layout for a design, obtain its anatomy via the canonical analysis of its projectors to show the confounding and aliasing inherent in the design.*

Description

Computes the canonical efficiency factors for the joint decomposition of two or more structures or sets of mutually orthogonally projectors (Brien and Bailey, 2009; Brien, 2017; Brien, 2019), orthogonalizing projectors in a set to those earlier in the set of projectors with which they are partially aliased. The results can be summarized in the form of a decomposition table that shows the confounding between sources from different sets. For examples of the function's use also see the vignette accessed via `vignette("DesignNotes", package="dae")` and for a discussion of its use see Brien, Sermarini and Demetro (2023).

Usage

```
designAnatomy(formulae, data, keep.order = TRUE, grandMean = FALSE,
              orthogonalize = "hybrid", labels = "sources",
              marginality = NULL, check.marginality = TRUE,
              which.criteria = c("aefficiency","eefficiency","order"),
              aliasing.print = FALSE,
              omit.projectors = c("pcanon", "combined"), ...)
```

Arguments

`formulae`	An object of class `list` whose components are of class `formula`. Usually, the terms in a single formula have the same status in the allocation of factors in the design. For example, all involve only factors that were allocated, or all involve factors that were recipients of allocated factors. The names of the components are used to identify the sources in the `summary.pcanon` object. They will also be used to name the `terms`, `sources` and `marginality` lists in the `pcanon.object`.
`data`	A `data.frame` contains the values of the factors and variables that occur in `formulae`.
`keep.order`	A `logical` indicating whether the terms should keep their position in the expanded `formula` projector, or reordered so that main effects precede two-factor interactions, which precede three-factor interactions and so on.

grandMean — A logical indicating whether the projector for the grand mean is to be included for each structure.

orthogonalize — A character vector indicating the method for orthogonalizing a projector to those for terms that occurred previously in a single formula. Three options are available: hybrid; differencing; eigenmethods. The hybrid option is the most general and uses the relationships between the projection operators for the terms in the formula to decide which projectors to substract and which to orthogonalize using eigenmethods. The differencing option subtracts, from the current projector, those previously orthogonalized projectors for terms whose factors are a subset of the current projector's factors. The eigemethods option recursively orthogonalizes the projects using an eigenanalysis of each projector with previously orthogonalized projectors. If a single value is given, it is used for all formulae.

labels — A character nominating the type of labels to be used in labelling the projectors, and which will be used also in the output tables, such the tables of the aliasing in the structure. The two alternatives are terms and sources. Terms have all factors/variables in it separated by colons (:). Sources have factors/variables in them that represent interactions separated by hashes (#); if some factors are nested within others, the nesting factors are surrounded by square brackets ([and]) and separated by colons (:). If some generalized, or combined, factors have no marginal terms, the constituent factors are separated by colons (:) and if they interact with other factors in the source they will be parenthesized.

marginality — A list that can be used to supply some or all of the marginality matrices when it is desired to overwrite calculated marginality matrices or when they are not calculated. If the list is the same length as the formulae list, they will be associated in parallel with the components of formulae, irrespective of the naming of the two lists. If the number of components in marginlaity is less than the number of components in formulae then both lists must be named so that those in the marginality list can be matched with those in the formulae list.

Each component of the marginality list must be either NULL or a square matrix consisting of zeroes and ones that gives the marginalites of the terms in the formula. It must have the row and column names set to the terms from the expanded formula, including being in the same order as these terms. The entry in the ith row and jth column will be one if the ith term is marginal to the jth term i.e. the column space of the ith term is a subspace of that for the jth term and so the source for the jth term is to be made orthogonal to that for the ith term. Otherwise, the entries are zero. A row and column should not be included for the grand mean even if grandMean is TRUE.

check.marginality — A logical indicating whether the marginality matrix, when it is supplied, is to be checked against that computed by pstructure.formula. It is ignored when orthogonalize is set to eigenmethods.

which.criteria — A character vector nominating the efficiency criteria to be included in the summary of aliasing between terms within a structure. It can be none, all or some combination of aefficiency, mefficiency, sefficiency, eefficiency, xefficiency, order and dforthog – for details see efficiency.criteria. If none, no summary is printed.

aliasing.print — A logical indicating whether the aliasing between sources is to be printed.

omit.projectors — A character vector of the types of projectors to omit from the returned pcanon

object. If pcanon is included in the vector then the projectors in these objects will be replaced with a numeric containing their degrees of freedom. If combined is included in the vector then the projectors for the combined decomposition will be replaced with a numeric containing their degrees of freedom. If none is included in the vector then no projectors will be omitted.

... further arguments passed to terms.

Details

For each formula supplied in formulae, the set of projectors is obtained using pstructure; there is one projector for each term in a formula. Then projs.2canon is used to perform an analysis of the canonical relationships between two sets of projectors for the first two formulae. If there are further formulae, the relationships between its projectors and the already established decomposition is obtained using projs.2canon. The core of the analysis is the determination of eigenvalues of the products of pairs of projectors using the results of James and Wilkinson (1971). However, if the order of balance between two projection matrices is 10 or more or the James and Wilkinson (1971) methods fails to produce an idempotent matrix, equation 5.3 of Payne and Tobias (1992) is used to obtain the projection matrices for their joint decompostion.

The hybrid method is recommended for general use. However, of the three methods, eigenmethods is least likely to fail, but it does not establish the marginality between the terms. It is often needed when there is nonorthogonality between terms, such as when there are several linear covariates. It can also be more efficeint in these circumstances.

The process can be computationally expensive, particularly for a large data set (500 or more observations) and/or when many terms are to be orthogonalized.

If the error Matrix is not idempotent should occur then, especially if there are many terms, one might try using set.daeTolerance to reduce the tolerance used in determining if values are either the same or are zero; it may be necessary to lower the tolerance to as low as 0.001. Also, setting orthogonalize to eigenmethods is worth a try.

Value

A pcanon.object.

Author(s)

Chris Brien

References

Brien, C. J. (2017) Multiphase experiments in practice: A look back. *Australian & New Zealand Journal of Statistics*, **59**, 327-352.

Brien, C. J. (2019) Multiphase experiments with at least one later laboratory phase . II. Northogonal designs. *Australian & New Zealand Journal of Statistics*, **61**, 234-268.

Brien, C. J. and R. A. Bailey (2009). Decomposition tables for multitiered experiments. I. A chain of randomizations. *The Annals of Statistics*, **36**, 4184-4213.

Brien, C. J., Sermarini, R. A., & Demetrio, C. G. B. (2023). Exposing the confounding in experimental designs to understand and evaluate them, and formulating linear mixed models for analyzing the data from a designed experiment. *Biometrical Journal*, accepted for publication.

James, A. T. and Wilkinson, G. N. (1971) Factorization of the residual operator and canonical decomposition of nonorthogonal factors in the analysis of variance. *Biometrika*, **58**, 279-294.

Payne, R. W. and R. D. Tobias (1992). General balance, combination of information and the analysis of covariance. *Scandinavian Journal of Statistics*, **19**, 3-23.

See Also

designRandomize, designLatinSqrSys, designPlot,
pcanon.object, p2canon.object, summary.pcanon, efficiencies.pcanon, pstructure ,
projs.2canon, proj2.efficiency, proj2.combine, proj2.eigen, efficiency.criteria, in package **dae**,
eigen.

projector for further information about this class.

Examples

```
## PBIBD(2) from p. 379 of Cochran and Cox (1957) Experimental Designs.
## 2nd edn Wiley, New York
PBIBD2.unit <- list(Block = 6, Unit = 4)
PBIBD2.nest <- list(Unit = "Block")
trt <- factor(c(1,4,2,5, 2,5,3,6, 3,6,1,4, 4,1,5,2, 5,2,6,3, 6,3,4,1))
PBIBD2.lay <- designRandomize(allocated = trt,
                              recipient = PBIBD2.unit,
                              nested.recipients = PBIBD2.nest)

##obtain combined decomposition and summarize
unit.trt.canon <- designAnatomy(formulae = list(unit=~ Block/Unit, trt=~ trt),
                                data = PBIBD2.lay)
summary(unit.trt.canon, which.criteria = c("aeff","eeff","order"))
summary(unit.trt.canon, which.criteria = c("aeff","eeff","order"), labels.swap = TRUE)

## Three-phase sensory example from Brien and Payne (1999)
## Not run:
data(Sensory3Phase.dat)
Eval.Field.Treat.canon <- designAnatomy(formulae = list(
                              eval= ~ ((Occasions/Intervals/Sittings)*Judges)/Positions,
                              field= ~ (Rows*(Squares/Columns))/Halfplots,
                              treats= ~ Trellis*Method),
                                        data = Sensory3Phase.dat)
summary(Eval.Field.Treat.canon, which.criteria =c("aefficiency", "order"))

## End(Not run)
```

---

designBlocksGGPlot *Adds block boundaries to a plot produced by* designGGPlot.

Description

This function adds block boundaries to a plot produced by designGGPlot. It allows control of the starting unit, through originrow and origincolumn, and the number of rows (nrows) and columns (ncolumns) from the starting unit that the blocks to be plotted are to cover.

Usage

```
designBlocksGGPlot(ggplot.obj, blockdefinition = NULL, blocksequence = FALSE,
                   originrow= 0, origincolumn = 0, nrows, ncolumns,
                   blocklinecolour = "blue", blocklinesize = 2,
                   facetstrips.placement = "inside",
                   printPlot = TRUE)
```

Arguments

ggplot.obj	An object produced by ggplot.
blockdefinition	A matrix of block sizes: • if there is only one row, then the first element is interpreted as the no. rows in each block and blocks with this number of rows are to be repeated across the rows of the design. • if there is more than one row, then each row of the matrix specifies a block, with the sequence of rows in the matrix specifying a corresponding sequence of blocks down the rows of the design. Similarly, a single value for a column specifies a repetition of blocks of that size across the columns of the design, while several column values specifies a sequence of blocks across the columns of the size specified.
blocksequence	A logical that determines whether block numbers are repetitions or sequences of block numbers.
originrow	A numeric speccifying the row after which the plotting of block boundaries is to start.
origincolumn	A numeric speccifying the column after which the plotting of block boundaries is to start.
nrows	A numeric the number of rows (nrows), from the starting unit, that the blocks to be plotted are to cover.
ncolumns	A numeric the number of columns (ncolumns), from the starting unit, that the blocks to be plotted are to cover.
blocklinecolour	A character string specifying the colour of the block boundary. See Colour specification under the par function.
blocklinesize	A numeric giving the width of the block boundary to be plotted.
facetstrips.placement	A character nominating where the strip is to be placed with respect to axes text and titles, either "inside" both text and titles, "outside.text" or "outside.title". This argument is important only when axes and strips are on the same side of the plot. When this occurs, the default is to place them inside the axis text. **Note:** This argument must be specified only once in the constructon of the plot and after every other aspect of the plot has been finalized. In particular, if designBlocksGGPlot is to called after designGGPlot to add block boundaries, then facetstrips.placement should be specified in the last call to designBlocksGGPlot, not in the call to designGGPlot.
printPlot	A logical indicating whether to print the plot after adding the block boundaries.

Value

An object of class "ggplot", formed by adding to the input ggplot.obj and which can be plotted using print.

Author(s)

Chris Brien

Source

Brien, C.J., Harch, B.D., Correll, R.L., and Bailey, R.A. (2011) Multiphase experiments with at least one later laboratory phase. I. Orthogonal designs. *Journal of Agricultural, Biological, and Environmental Statistics*, 16:422-450.

See Also

designGGPlot, par, DiGGer

Examples

```
## Construct a randomized layout for the split-unit design described by
## Brien et al. (2011, Section 5)
split.sys <- cbind(fac.gen(list(Months = 4, Athletes = 3, Tests = 3)),
                   fac.gen(list(Intensities = LETTERS[1:3], Surfaces = 3),
                           times = 4))
split.lay <- designRandomize(allocated = split.sys[c("Intensities", "Surfaces")],
                             recipient = split.sys[c("Months", "Athletes", "Tests")],
                             nested.recipients = list(Athletes = "Months",
                                                      Tests = c("Months", "Athletes")),
                             seed = 2598)
## Plot the design
cell.colours <- c("lightblue","lightcoral","lightgoldenrod","lightgreen","lightgrey",
                  "lightpink","lightsalmon","lightcyan","lightyellow","lightseagreen")

split.lay <- within(split.lay,
                    Treatments <- fac.combine(list(Intensities, Surfaces),
                                              combine.levels = TRUE))
plt <- designGGPlot(split.lay, labels = "Treatments",
                    row.factors = "Tests", column.factors = c("Months", "Athletes"),
                    colour.values = cell.colours[1:9], label.size = 6,
                    blockdefinition = rbind(c(3,1)), blocklinecolour = "darkgreen",
                    printPlot = FALSE)
#Add Month boundaries
designBlocksGGPlot(plt, nrows = 3, ncolumns = 3, blockdefinition = rbind(c(3,3)))



#### A layout for a growth cabinet experiment that allows for edge effects
data(Cabinet1.des)
plt <- designGGPlot(Cabinet1.des, labels = "Combinations", cellalpha = 0.75,
                    title = "Lines and Harvests allocation for Cabinet 1",
                    printPlot = FALSE)

## Plot Mainplot boundaries
plt <- designBlocksGGPlot(plt, blockdefinition = cbind(4,16), originrow= 1 ,
                          blocklinecolour = "green", nrows = 9, ncolumns = 16,
```

```
                          printPlot = FALSE)
plt <- designBlocksGGPlot(plt, blockdefinition = cbind(1,4),
                          blocklinecolour = "green", nrows = 1, ncolumns = 16,
                          printPlot = FALSE)
plt <- designBlocksGGPlot(plt, blockdefinition = cbind(1,4), originrow= 9,
                          blocklinecolour = "green", nrows = 10, ncolumns = 16,
                          printPlot = FALSE)
## Plot all 4 block boundaries
plt <- designBlocksGGPlot(plt, blockdefinition = cbind(8,5,5,4), blocksequence = TRUE,
                          origincolumn = 1, originrow= 1,
                          blocklinecolour = "blue", nrows = 9, ncolumns = 15,
                          printPlot = FALSE)
plt <- designBlocksGGPlot(plt, blockdefinition = cbind(10,16),
                          blocklinecolour = "blue", nrows = 10, ncolumns = 16,
                          printPlot = FALSE)
## Plot border and internal block boundaries only
plt <- designBlocksGGPlot(plt, blockdefinition = cbind(8,14), origincolumn = 1, originrow= 1,
                          blocklinecolour = "blue", nrows = 9, ncolumns = 15,
                          printPlot = FALSE)
plt <- designBlocksGGPlot(plt, blockdefinition = cbind(10,16),
                          blocklinecolour = "blue", nrows = 10, ncolumns = 16)
```

`designGGPlot` *Plots labels on two-way grids of coloured cells using* `ggplot2` *to represent an experimental design*

Description

Plots the `labels` in a grid of cells specified by `row.factors` and `column.factors`. The cells can be coloured by the values of the column specified by `column.name` and can be divided into facets by specifying multiple row and or column factors.

Usage

```
designGGPlot(design, labels = NULL, label.size = NULL,
             row.factors = "Rows", column.factors = "Columns",
             scales.free = "free", facetstrips.switch = NULL,
             facetstrips.placement = "inside",
             cellfillcolour.column = NULL, colour.values = NULL,
             cellalpha = 1, celllinetype = "solid", celllinesize = 0.5,
             celllinecolour = "black", cellheight = 1, cellwidth = 1,
             reverse.x = FALSE, reverse.y = TRUE, x.axis.position = "top",
             xlab, ylab, title, labeller = label_both,
             title.size = 15, axis.text.size = 15,
             blocksequence = FALSE, blockdefinition = NULL,
             blocklinecolour = "blue", blocklinesize = 2,
             printPlot = TRUE, ggplotFuncs = NULL, ...)
```

Arguments

`design`	A `data.frame` containing `labels`, `column.factors`, `row.factors` and, if specified, `colour.column`.

labels — A character giving the name of the column in data containing the labels to be plotted on the grid. If labels is NULL, no labels are added.

label.size — A numeric giving the size of the labels.

row.factors — A character giving the names of the factors (or numerics) in data that index the rows of the plot grid used to represent the design. If there is more than one name, then facet_grid is used to facet the plot in the y direction, based on all but the last name. The factor corresponding to the last name will index the rows in each facet.

column.factors — A character giving the names of the factors (or numerics) in data that index the columns of the plot grid used to represent the design. If there is more than one name, then facet_grid is used to facet the plot in the x direction, based on all but the last name. The factor corresponding to the last name will index the columns in each facet.

scales.free — When plots are facetted, a character specifying whether scales are shared across all facets (fixed), or vary across rows (free_x), columns (free_y), or both rows and columns (the default, free). The free_x, free_y and free options may not work when the plot grid is indexed using numerics.

facetstrips.switch — When plots are facetted, the strip text are displayed on the top and right of the plot by default. If facetstrips.switch is "x", the top strip text will be switched to the bottom. If "y", the right-hand side labels will be switched to the left. The argument can also be set to "both". The argument facetstrips.placement can be used to change the relationship between the strip text and the axis.text and the axis.title.

facetstrips.placement — A character nominating where the strip is to be placed with respect to axes text and titles, either "inside" both text and titles, "outside.text" or "outside.title". This argument is important only when axes and strips are on the same side of the plot. When this occurs, the default is to place them inside the axis text. **Note:** This argument must be specified only once in the constructon of the plot and after every other aspect of the plot has been finalized. In particular, if designBlocksGGPlot is to called after designGGPlot to add block boundaries, then facetstrips.placement should be specified in the call to designBlocksGGPlot, not in the call to designGGPlot.

reverse.x — A logical which, if true, causes the order of values on the x-axis to be reversed, the natural order being to increase from left to right.

reverse.y — A logical which, if true, causes the order of values on the y-axis to be reversed, the natural order being to increase from bottom to top.

x.axis.position — A character giving the position of the x-axis; can be top or bottom.

cellfillcolour.column — A character giving the name of the column in data that is to be used to vary the colour the used to fill a cell.

colour.values — A character giving the name or names of the colours to be used in filling the cell. If cellfillcolour.column is not NULL then the number of colours sepcified needs to match the number of unique values in the cellfillcolour.column.

cellalpha — A numeric specifying the degree of transparency to be used in cell fill. It is a ratio in which the denominator specifies the number of points (or lines) that must be overplotted to give a solid cover.

celllinetype	A numeric or character giving the type of line for the cell border. An integer or name: 0 = blank, 1 = solid, 2 = dashed, 3 = dotted, 4 = dotdash, 5 = longdash, 6 = twodash. For more information see vignette("ggplot2-specs").
celllinesize	A numeric specifying the size of the line in mm.
celllinecolour	A character giving the name of the colour to use for the cell outline.
cellheight	A numeric specifying the height of a cell.
cellwidth	A numeric specifying the width of of a cell.
xlab	Label for the x-axis. By default it is the last name in the column.factors.
ylab	Label for the y-axis. By default it is the last name in the row.factors.
title	Title for plot window. By default it is "Plot of labels".
labeller	A function for specifying the formatting of the strip labels of the facet grids used when there is more than one row.factors or column.factors. (See labellers for ggplot2.)
title.size	A numeric giving the size for all titles: xlab, ylab and title.
axis.text.size	A numeric giving the size for tick labels.
blocksequence	A logical that determines whether block numbers are repetitions or sequences of block numbers.
blockdefinition	A matrix of block sizes: • if there is only one row, then the first element is interpreted as the no. rows in each block and blocks with this number of rows are to be repeated across the rows of the design. • if there is more than one row, then each row of the matrix specifies a block, with the sequence of rows in the matrix specifying a corresponding sequence of blocks down the rows of the design. Similarly, a single value for a column specifies a repetition of blocks of that size across the columns of the design, while several column values specifies a sequence of blocks across the columns of the size specified.
blocklinecolour	A character string specifying the colour of the block boundary. See also the scale_colour_* functions or Colour specification under the par function.
blocklinesize	A numeric giving the width of the block boundary to be plotted.
printPlot	A logical indicating whether to print the plot produced.
ggplotFuncs	A list, each element of which contains the results of evaluating a ggplot function. It is created by calling the list function with a ggplot function call for each element. These functions are applied in creating the ggplot object.
...	Other arguments that are passed down to the geom_text call that plots the labels.

Value

An object of class "ggplot", which can be plotted using print.

Author(s)

Chris Brien

See Also

designBlocksGGPlot, fac.combine in package **dae**, designPlot.

Examples

```
#### Plot a randomized complete block design
Treatments <- factor(rep(1:6, times = 5))
RCBD.lay <- designRandomize(allocated = Treatments,
                            recipient = list(Blocks = 5, Units = 6),
                            nested.recipients = list(Units = "Blocks"),
                            seed = 74111)
designGGPlot(RCBD.lay, labels = "Treatments", label.size = 5,
             row.factors = "Blocks", column.factors = "Units",
             blockdefinition = cbind(1,5))

## Plot without labels
designGGPlot(RCBD.lay, cellfillcolour.column = "Treatments",
             row.factors = "Blocks", column.factors = "Units",
             colour.values = c("lightblue","lightcoral","lightgoldenrod",
                               "lightgreen","lightgrey", "lightpink"),
             blockdefinition = cbind(1,6))


#### Plot a lattice square design
data(LatticeSquare_t49.des)
designGGPlot(LatticeSquare_t49.des, labels = "Lines", label.size = 5,
             row.factors = c("Intervals", "Runs"), column.factors = "Times",
             blockdefinition = cbind(7,7))
```

---

designLatinSqrSys *Generate a systematic plan for a Latin Square design*

Description

Generates a systematic plan for a Latin Square design using the method of cycling the integers 1 to the number of treatments. The start of the cycle for each row, or the first column, can be specified as a vector of integers.

Usage

```
designLatinSqrSys(order, start = NULL)
```

Arguments

order	The number of treatments.
start	A numeric containing order unique values between one and order. These are interpreted as the value for the fist column for each row. If NULL, 1:order is used.

Value

A numeric containing order x order integers between 1 and order such that, when the numeric is considered as a square matrix of size order, each integer occurs once and only once in each row and column of the matrix.

See Also

designRandomize, designPlot, designAnatomy in package **dae**.

Examples

```
matrix(designLatinSqrSys(5, start = c(seq(1, 5, 2), seq(2, 5, 2))), nrow=5)
designLatinSqrSys(3)
```

---

designPlot *A graphical representation of an experimental design using labels stored in a matrix.*

Description

This function uses labels, usually derived from treatment and blocking factors from an experimental design and stored in a matrix, to build a graphical representation of the matrix, highlighting the position of certain labels . It is a modified version of the function supplied with DiGGer. It includes more control over the labelling of the rows and columns of the design and allows for more flexible plotting of designs with unequal block size.

Usage

```
designPlot(designMatrix, labels = NULL, altlabels = NULL, plotlabels = TRUE,
           rtitle = NULL, ctitle = NULL,
           rlabelsreverse = FALSE, clabelsreverse = FALSE,
           font = 1, chardivisor = 2, rchardivisor = 1, cchardivisor = 1,
           cellfillcolour = NA, plotcellboundary = TRUE,
           rcellpropn = 1, ccellpropn = 1,
           blocksequence = FALSE, blockdefinition = NULL,
           blocklinecolour = 1, blocklinewidth = 2,
           rotate = FALSE, new = TRUE, ...)
```

Arguments

designMatrix	A matrix containing a set of numerics or characters being the labels as they have been assigned to the cells of the grid represented by the matrix.
labels	A numeric or character vector giving the cells in designMatrix that are to be plotted in this call to designPlot. If NULL then all the cells are plotted. What is actually plotted for a cell is controlled jointly by labels, plotlabels, altlabels, plotcellboundary and cellfillcolour. If plotlabels is TRUE and altlabels is NULL then labels are plotted in the cells, unless labels is NULL when the labels in designMatrix are plotted. Whatever is being plotted, altlabels and cellfillcolour must have an appropriate number of values. See text for more information on specifying the labels.
altlabels	Either a character vector containing an alternative set of labels for the labels currently being plotted or a single integer specifying an alternative symbol to be used in plotting cells when plotlabels is TRUE. The length of altlabels must be one or the same length as labels, unless labels is NULL in which case it must equal the number of unique labels in designMatrix.

If altlabels is NULL, the labels specified in labels are plotted when plotlabels is TRUE. If labels is also NULL, the labels in designMatrix are plotted. See text for more information on specifying the labels.

plotlabels A logical to indicate whether labels are to be plotted in the cells. If TRUE, print all labels or the specific labels listed in labels. If FALSE, no labels are printed in the cells.

rtitle A character string to use as a title for rows of the plot. If rtitle is NULL then no title is plotted.

ctitle A character string to use as a title for columns of the plot. If ctitle is NULL then no title is plotted.

rlabelsreverse A logical indicating whether to reverse the row labels.

clabelsreverse A logical indicating whether to reverse the column labels.

font An integer specifying the font to be used for row and column labelling. See par for further details.

chardivisor A numeric that changes the size of text and symbols in the cells by dividing the default size by it.

rchardivisor A numeric that changes the size of the labels of the rows of the design by dividing the default size by it.

cchardivisor A numeric that changes the size of the labels of the columns of the design by dividing the default size by it.

cellfillcolour A character string specifying the colour of the fill for the cells to be plotted in this call. If there is only one colour then all cells being plotted with that colour. If there is more than one colour then, unless labels is NULL, the number of colours must at least equal the number of labels and then the fill colours will be matched, one for one from the first colour, with the labels. If labels is NULL then the number of colours must at least equal the number of unique labels in designMatrix. The default, NA, is to leave ther cells unfilled.

See also Colour specification under the par function.

plotcellboundary

A logical indicting whether a boundary is to plotted around a cell.

rcellpropn a value between 0 and 1 giving the proportion of the standard row size of a cell size to be plotted as a cell.

ccellpropn a value between 0 and 1 giving the proportion of the standard column size of a cell size to be plotted as a cell.

blocksequence A logical that determines whether block numbers are repetitions or sequences of block numbers.

blockdefinition

A matrix of block sizes:

- if there is only one row, then the first element is interpreted as the no. rows in each block and blocks with this number of rows are to be repeated across the rows of the design.
- if there is more than one row, then each row of the matrix specifies a block, with the sequence of rows in the matrix specifying a corresponding sequence of blocks down the rows of the design.

Similarly, a single value for a column specifies a repetition of blocks of that size across the columns of the design, while several column values specifies a sequence of blocks across the columns of the size specified.

`blocklinecolour`
: A `character` string specifying the colour of the block boundary.
See also `Colour specification` under the `par` function.

`blocklinewidth`
: A `numeric` giving the width of the block boundary to be plotted.

`rotate`
: A `logical` which, if `TRUE`, results in the matrix being rotated 90 degrees for plotting.

`new`
: A `logical` indicating if a new plot is to be produced or the current plot is added to.

`...`
: further arguments passed to `polygon` in plotting the cell.

Value

no values are returned, but a plot is produced.

Author(s)

Chris Brien

References

Coombes, N. E. (2009). *DiGGer design search tool in R*. http://nswdpibiom.org/austatgen/software/

See Also

`blockboundaryPlot`, `designPlotlabels`, `designLatinSqrSys`, `designRandomize`, `designAnatomy` in package **dae**.
Also, `par`, `polygon`, `DiGGer`

Examples

```
## Not run:
  designPlot(des.mat, labels=1:4, cellfillcolour="lightblue", new=TRUE,
             plotcellboundary = TRUE, chardivisor=3,
             rtitle="Lanes", ctitle="Positions",
             rcellpropn = 1, ccellpropn=1)
  designPlot(des.mat, labels=5:87, plotlabels=TRUE, cellfillcolour="grey", new=FALSE,
             plotcellboundary = TRUE, chardivisor=3)
  designPlot(des.mat, labels=88:434, plotlabels=TRUE, cellfillcolour="lightgreen",
             new=FALSE, plotcellboundary = TRUE, chardivisor=3,
             blocksequence=TRUE, blockdefinition=cbind(4,10,12),
             blocklinewidth=3, blockcolour="blue")
## End(Not run)
```

designPlotlabels *Plots labels on a two-way grid using* ggplot2

Description

Plots the labels in a grid specified by grid.xand grid.y. The labels can be coloured by the values of the column specified by column.name.

Usage

```
designPlotlabels(data, labels, grid.x = "Columns", grid.y = "Rows",
                 colour.column=NULL, colour.values=NULL,
                 reverse.x = FALSE, reverse.y = TRUE,
                 xlab, ylab, title, printPlot = TRUE, ggplotFuncs = NULL, ...)
```

Arguments

data	A data.frame containing labels, grid.x, grid.y and, if specified, colour.column.
labels	A character giving the name of the column in data containing the labels to be plotted on the grid.
grid.x	A character giving the name of the column in data that specifies the x-coordinates of the plot grid.
grid.y	A character giving the name of the column in data that specifies the y-coordinates of the plot grid.
reverse.x	A logical which, if true, causes the order of values on the x-axis to be reversed.
reverse.y	A logical which, if true, causes the order of values on the y-axis to be reversed.
colour.column	A character giving the name of the column in data that is to be used to colour the values plotted on the grid.
colour.values	A character giving the name of the column in data that is to be used to colour the values plotted on the grid.
xlab	Label for the x-axis. By default it is the name of the grid.x.
ylab	Label for the y-axis. By default it is the name of the grid.y.
title	Title for plot window. By default it is "Plot of labels".
printPlot	A logical indicating whether to print the plot.
ggplotFuncs	A list, each element of which contains the results of evaluating a ggplot function. It is created by calling the list function with a ggplot function call for each element. These functions are applied in creating the ggplot object.
...	Other arguments that are passed down to the geom_text call that plots the labels.

Value

An object of class "ggplot", which can be plotted using print.

Author(s)

Chris Brien

See Also

fac.combine in package **dae**, designPlot.

Examples

```
Treatments <- factor(rep(1:6, times = 5))
RCBD.lay <- designRandomize(allocated = Treatments,
                            recipient = list(Blocks = 5, Units = 6),
                            nested.recipients = list(Units = "Blocks"),
                            seed = 74111)
designPlotlabels(RCBD.lay, labels = "Treatments",
                 grid.x = "Units", grid.y = "Blocks",
                 colour.column = "Treatments", size = 5)
```

---

designRandomize *Randomize allocated to recipient factors to produce a layout for an experiment*

Description

A systematic design is specified by a set of allocated factors that have been assigned to a set of recipient factors. In textbook designs the allocated factors are the treatment factors and the recipient factors are the factors indexing the units. To obtain a randomized layout for a systematic design it is necessary to provide (i) the systematic arrangement of the allocated factors, (ii) a list of the recipient factors or a data.frame with their values, and (iii) the nesting of the recipient factors for the design being randomized. Given this information, the allocated factors will be randomized to the recipient factors, taking into account the nesting between the recipient factors for the design. However, allocated factors that have different values associated with those recipient factors that are in the except vector will remain unchanged from the systematic design.

Also, if allocated is NULL then a random permutation of the recipient factors is produced that is consistent with their nesting as specified by nested.recipients.

For examples of its use also see the vignette accessed via vignette("DesignNotes", package="dae") and for a discussion of its use see Brien, Sermarini and Demetro (2023).

Usage

```
designRandomize(allocated = NULL, recipient, nested.recipients = NULL,
                except = NULL, seed = NULL, unit.permutation = FALSE, ...)
```

Arguments

allocated	A factor or a data.frame containing the systematically allocated values of the factor(s). If NULL, a random permutation of the recipient factors is produced that is consistent with their nesting as specified by nested.recipients.
recipient	A data.frame or a list of factors, along with their levels that specify the set of recipient factors that are allocated levels of the allocated factors. If a list, the name of each component of the list is a factor name and the component is either (i) a single numeric value that is the number of levels, (ii) a numeric vector that contains the levels of the factor, (iii) or a character

vector that contains the labels of the levels of the factor. The values of factors will be generated in standard order using fac.gen and so the values in allocated must match this.

nested.recipients
: A list of the recipient factors that are nested in other factors in recipient. The name of each component is the name of a factor that is nested and the component is a character vector containing the factors within which it is nested. The randomization is controlled by nested.recipients: nested recipient factors are permuted within those factors that nest them. Only the nesting is specified: it is assumed that if two factors are not nested then they must be crossed. It is emphasized that the nesting is a property of the design that is being employed (it is only partly based on the intrinsic or physical crossing and nesting).

except
: A character vector containing the names of recipient factors that are to be excepted from the permutation; any allocated factors whose values differ between the levels of the factors in this vector will not have those values randomized.

seed
: A single numeric value, interpreted as an integer, that specifies the starting value of the random number generator.

unit.permutation
: A logical indicating whether to include the .Unit and .Permutation columns in the data.frame.

...
: Further arguments passed to or from other methods. Unused at present.

Details

A systematic design is specified by the matching of the supplied allocated and recipient factors. If recipient is a list then fac.gen is used to generate a data.frame with the combinations of the levels of the recipient factors in standard order. Although, the data.frames are not combined at this stage, the systematic design is the combination, by columns, of the values of the allocated factors with the values of recipient factors in the recipient data.frame.

The method of randomization described by Bailey (1981) is used to randomize the allocated factors to the recipient factors. That is, a permutation of the recipient factors is obtained that respects the nesting for the design, but does not permute any of the factors in the except vector. A permutation is generated for all combinations of the recipient factors, except that a nested factor, specifed using the nested.recipients argument, cannot occur in a combination without its nesting factor(s). These permutations are combined into a single, units permutation that is applied to the recipient factors. Then the data.frame containing the permuted recipient factors and that containng the unpermuted allocated factors are combined columnwise, as in cbind. To produce the randomized layout, the rows of the combined data.frame are reordered so that its recipient factors are in either standard order or, if a data.frame was suppled to recipient, the same order as for the supplied data.frame.

The .Units and .Permutation vectors enable one to swap between this combined, units permutation and the randomized layout. The *i*th value in .Permutation gives the unit to which unit *i* was assigned in the randomization.

Value

A data.frame with the values for the recipient and allocated factors that specify the layout for the experiment and, if unit.permutation is TRUE, the values for .Units and .Permutation vectors.

Author(s)

Chris Brien

References

Bailey, R.A. (1981) A unified approach to design of experiments. *Journal of the Royal Statistical Society, Series A*, **144**, 214–223.

See Also

fac.gen, designLatinSqrSys, designPlot, designAnatomy in package **dae**.

Examples

```
## Generate a randomized layout for a 4 x 4 Latin square
## (the nested.recipients argument is not needed here as none of the
## factors are nested)
## Firstly, generate a systematic layout
LS.sys <- cbind(fac.gen(list(row = c("I","II","III","IV"),
                             col = c(0,2,4,6))),
                treat = factor(designLatinSqrSys(4), label = LETTERS[1:4]))
## obtain randomized layout
LS.lay <- designRandomize(allocated = LS.sys["treat"],
                          recipient = LS.sys[c("row","col")],
                          seed = 7197132, unit.permutation = TRUE)
LS.lay[LS.lay$.Permutation,]

## Generate a randomized layout for a replicated randomized complete
## block design, with the block factors arranged in standard order for
## rep then plot and then block
## Firstly, generate a systematic order such that levels of the
## treatment factor coincide with plot
RCBD.sys <- cbind(fac.gen(list(rep = 2, plot=1:3, block = c("I","II"))),
                  tr = factor(rep(1:3, each=2, times=2)))
## obtain randomized layout
RCBD.lay <- designRandomize(allocated = RCBD.sys["tr"],
                            recipient = RCBD.sys[c("rep", "block", "plot")],
                            nested.recipients = list(plot = c("block","rep"),
                                                     block="rep"),
                            seed = 9719532,
                            unit.permutation = TRUE)
#sort into the original standard order
RCBD.perm <- RCBD.lay[RCBD.lay$.Permutation,]
#resort into randomized order
RCBD.lay <- RCBD.perm[order(RCBD.perm$.Units),]

## Generate a layout for a split-unit experiment in which:
## - the main-unit factor is A with 4 levels arranged in
##   a randomized complete block design with 2 blocks;
## - the split-unit factor is B with 3 levels.
## Firstly, generate a systematic layout
SPL.sys <- cbind(fac.gen(list(block = 2, main.unit = 4, split.unit = 3)),
                 fac.gen(list(A = 4, B = 3), times = 2))
## obtain randomized layout
SPL.lay <- designRandomize(allocated = SPL.sys[c("A","B")],
                           recipient = SPL.sys[c("block", "main.unit", "split.unit")],
```

```
                          nested.recipients = list(main.unit = "block",
                                                   split.unit = c("block", "main.unit")),
                          seed=155251978)

## Generate a permutation of Seedlings within Species
seed.permute <- designRandomize(recipient = list(Species = 3, Seedlings = 4),
                                nested.recipients = list(Seedlings = "Species"),
                                seed = 75724, except = "Species",
                                unit.permutation = TRUE)
```

`designTwophaseAnatomies` *Given the layout for a design and three structure formulae, obtain the anatomies for the (i) two-phase, (ii) first-phase, (iii) cross-phase, treatments, and (iv) combined-units designs.*

Description

Uses `designAnatomy` to obtain the four species of designs, described by Brien (2019), that are associated with a standard two-phase design: the anatomies for the (i) two-phase, (ii) first-phase, (iii) cross-phase, treatments, and (iv) combined-units designs. (The names of the last two designs in Brien (2019) were cross-phase and second-phase designs.) For the standard two-phase design, the first-phase design is the design that allocates first-phase treatments to first-phase units. The cross-phase, treatments design allocates the first-phase treatments to the second-phase units and the combined-units design allocates the the first-phase units to the second-phase units. The two-phase design combines the other three species of designs. However, it is not mandatory that the three formula correspond to second-phase units, first-phase units and first-phase treatments, respectively, as is implied above; this is just the correspondence for a standard two-phase design. The essential requirement is that three structure formulae are supplied. For example, if there are both first- and second-phase treatments in a two-phase design, the third formula might involve the treatment factors from both phases. In this case, the default anatomy titles when printing occurs will not be correct, but can be modifed using the `titles` argument.

Usage

```
designTwophaseAnatomies(formulae, data, which.designs = "all",
                        printAnatomies = TRUE, titles,
                        orthogonalize = "hybrid",
                        marginality = NULL,
                        which.criteria = c("aefficiency", "eefficiency",
                                           "order"), ...)
```

Arguments

`formulae`	An object of class `list` with three components of class `formula`. Usually, the terms in a single formula have the same status in the allocation of factors in the design. For example, all involve only factors that were allocated, or all involve factors that were recipients of allocated factors. The names of the components are used to identify the sources in the `summary.pcanon` object. They will also be used to name the `terms`, `sources` and `marginality` lists in the `pcanon.object`.
`data`	A `data.frame` contains the values of the factors and variables that occur in `formulae`.

`which.designs` A `character` vector indicating the species of designs that are to be obtained. It should include one or more of `two-phase`, `first-phase`, `cross-phase` and `combined-units`; `all`, the default, results in all four being obtained.

`printAnatomies` A `logical` indicating whether or not the anatomies are to be printed.

`titles` A `character` vector of length four providing titles for the printed anatomies. It should have the titles, in the following order, for the antomies based on : (i) all three `formulae`, (ii) the second and third `formulae`, (iii) the first and third `formulae`, and (iv) the first and second `formulae`. If any element of `titles` is `NA` then that element is replaced with the corresponding default element of `titles`, these being, in order: `Anatomy for the full two-phase design`; `Anatomy for the first-phase design`; `Anatomy for the cross-phase, treatments design`; and `Anatomy for the combined-units design`. The titles generated will be saved as an attribute of the returned `list`.

`orthogonalize` A `character` vector indicating the method for orthogonalizing a projector to those for terms that occurred previously in a single formula. Three options are available: `hybrid`; `differencing`; `eigenmethods`. The `hybrid` option is the most general and uses the relationships between the projection operators for the terms in the `formula` to decide which projectors to substract and which to orthogonalize using eigenmethods. The `differencing` option subtracts, from the current projector, those previously orthogonalized projectors for terms whose factors are a subset of the current projector's factors. The `eigemethods` option recursively orthogonalizes the projects using an eigenanalysis of each projector with previously orthogonalized projectors. If a single value is given, it is used for all formulae.

`marginality` A `list` that can be used to supply some or all of the marginality matrices when it is desired to overwrite calculated marginality matrices or when they are not calculated. If the `list` is the same length as the `formulae` `list`, they will be associated in parallel with the components of `formulae`, irrespective of the naming of the two `list`s. If the number of components in `marginlaity` is less than the number of components in `formulae` then both `list`s must be named so that those in the `marginality` `list` can be matched with those in the `formulae` `list`.

Each component of the `marginality` `list` must be either `NULL` or a square `matrix` consisting of zeroes and ones that gives the marginalites of the terms in the formula. It must have the row and column names set to the terms from the expanded `formula`, including being in the same order as these terms. The entry in the ith row and jth column will be one if the ith term is marginal to the jth term i.e. the column space of the ith term is a subspace of that for the jth term and so the source for the jth term is to be made orthogonal to that for the ith term. Otherwise, the entries are zero. A row and column should not be included for the grand mean even if `grandMean` is `TRUE`.

`which.criteria` A `character` vector nominating the efficiency criteria to be included in the summary of aliasing between terms within a structure. It can be `none`, `all` or some combination of `aefficiency`, `mefficiency`, `sefficiency`, `eefficiency`, `xefficiency`, `order` and `dforthog` – for details see `efficiency.criteria`. If `none`, no summary is printed.

`...` further arguments passed to `designAnatomy`.

Details

To produce the anatomies, `designAnatomy` is called. The two-phase anatomy is based on the three `formulae` supplied in `formulae`, the first-phase anatomy uses the second and third `formulae`, the

cross-phase, treatments anatomy derives from the first and third `formulae` and the combined-units anatomy is obtained with the first and second `formulae`.

Value

A `list` containing the components `twophase`, `first`, `cross` and `combined`.Each contains the `pcanon.object` for one of the four designs produced by `designTwophaseAnatomies`, unless it is `NULL` because the design was omitted from the `which.designs` argument. The returned `list` has an attribute `titles`, being a `character` vector of length four and containing the titles used in printing the anatomies.

Author(s)

Chris Brien

References

Brien, C. J. (2017) Multiphase experiments in practice: A look back. *Australian & New Zealand Journal of Statistics*, **59**, 327-352.

Brien, C. J. (2019) Multiphase experiments with at least one later laboratory phase . II. Northogonal designs. *Australian & New Zealand Journal of Statistics***61**, 234-268.

See Also

`designAnatomy`, `pcanon.object`, `p2canon.object`, `summary.pcanon`, `efficiencies.pcanon`, `pstructure` , `projs.2canon`, `proj2.efficiency`, `proj2.combine`, `proj2.eigen`, `efficiency.criteria`, in package **dae**, `eigen`.

`projector` for further information about this class.

Examples

```
#'## Microarray example from Jarrett & Ruggiero (2008) - see Brien (2019)
jr.lay <- fac.gen(list(Set = 7, Dye = 2, Array = 3))
jr.lay <- within(jr.lay,
                 {
                   Block <- factor(rep(1:7, each=6))
                   Plant <- factor(rep(c(1,2,3,2,3,1), times=7))
                   Sample <- factor(c(rep(c(2,1,2,2,1,1, 1,2,1,1,2,2), times=3),
                                      2,1,2,2,1,1))
                   Treat <- factor(c(1,2,4,2,4,1, 2,3,5,3,5,2, 3,4,6,4,6,3,
                                     4,5,7,5,7,4, 5,6,1,6,1,5, 6,7,2,7,2,6,
                                     7,1,3,1,3,7),
                                   labels=c("A","B","C","D","E","F","G"))
                 })

jr.anat <- designTwophaseAnatomies(formulae = list(array = ~ (Set:Array)*Dye,
                                                   plot = ~ Block/Plant/Sample,
                                                   trt = ~ Treat),
                                   which.designs = c("first","cross"),
                                   data = jr.lay)

## Three-phase sensory example from Brien and Payne (1999)
## Not run:
data(Sensory3Phase.dat)
Sensory.canon <- designTwophaseAnatomies(formulae = list(
```

```
                                eval= ~ ((Occasions/Intervals/Sittings)*Judges)/Positions,
                                field= ~ (Rows*(Squares/Columns))/Halfplots,
                                treats= ~ Trellis*Method),
                                          data = Sensory3Phase.dat)

## End(Not run)
```

`detect.diff` *Computes the detectable difference for an experiment*

Description

Computes the delta that is detectable for specified replication, power, alpha.

Usage

```
detect.diff(rm=5, df.num=1, df.denom=10, sigma=1, alpha=0.05, power=0.8,
            tol = 0.001, print=FALSE)
```

Arguments

`rm`	The number of observations used in computing a mean.
`df.num`	The degrees of freedom of the numerator of the F for testing the term involving the means.
`df.denom`	The degrees of freedom of the denominator of the F for testing the term involving the means.
`sigma`	The population standard deviation.
`alpha`	The significance level to be used.
`power`	The minimum power to be achieved.
`tol`	The maximum difference tolerated between the power required and the power computed in determining the detectable difference.
`print`	`TRUE` or `FALSE` to have or not have a table of power calculation details printed out.

Value

A single `numeric` value containing the computed detectable difference.

Author(s)

Chris Brien

See Also

`power.exp`, `no.reps` in package **dae**.

Examples

```
## Compute the detectable difference for a randomized complete block design
## with four treatments given power is 0.8 and alpha is 0.05.
rm <- 5
detect.diff(rm = rm, df.num = 3, df.denom = 3 * (rm - 1),sigma = sqrt(20))
```

efficiencies *Extracts the canonical efficiency factors from a* pcanon.object *or a* p2canon.object.

Description

Produces a list containing the canonical efficiency factors for the joint decomposition of two or more sets of projectors (Brien and Bailey, 2009) obtained using designAnatomy or projs.2canon.

Usage

```
## S3 method for class 'pcanon'
efficiencies(object, which = "adjusted", ...)
## S3 method for class 'p2canon'
efficiencies(object, which = "adjusted", ...)
```

Arguments

object	A pcanon.object or an object of class p2canon produced by projs.2canon.
which	A character string, either adjusted or pairwise. For adjusted, the canonical efficiency factor are adjusted for other projectors from from the same set. For pairwise, they are the unadjusted canonical efficiency factors between pairs of projectors consisting of one projector from each of two sets.
...	Further arguments passed to or from other methods. Unused at present.

Value

For a pcanon.object, a list with a component for each component of object, except for the last component – for more information about the components see pcanon.object .

For a p2canon object, a list with a component for each element of the Q1 argument from projs.2canon. Each component is list, each its components corresponding to an element of the Q2 argument from projs.2canon

Author(s)

Chris Brien

References

Brien, C. J. and R. A. Bailey (2009). Decomposition tables for multitiered experiments. I. A chain of randomizations. *The Annals of Statistics*, **36**, 4184 - 4213.

See Also

designAnatomy, summary.pcanon, proj2.efficiency, proj2.combine, proj2.eigen, pstructure in package **dae**, eigen.

projector for further information about this class.

Examples

```
## PBIBD(2) from p. 379 of Cochran and Cox (1957) Experimental Designs.
## 2nd edn Wiley, New York
PBIBD2.unit <- list(Block = 6, Unit = 4)
PBIBD2.nest <- list(Unit = "Block")
trt <- factor(c(1,4,2,5, 2,5,3,6, 3,6,1,4, 4,1,5,2, 5,2,6,3, 6,3,4,1))
PBIBD2.lay <- designRandomize(allocated = trt,
                              recipient = PBIBD2.unit,
                              nested.recipients = PBIBD2.nest)

##obtain combined decomposition using designAnatomy and get the efficiencies
unit.trt.canon <- designAnatomy(list(unit=~ Block/Unit, trt=~ trt), data = PBIBD2.lay)
efficiencies.pcanon(unit.trt.canon)

##obtain the projectors for each formula using pstructure
unit.struct <- pstructure(~ Block/Unit, data = PBIBD2.lay)
trt.struct <- pstructure(~ trt, data = PBIBD2.lay)

##obtain combined decomposition projs.2canon and get the efficiencies
unit.trt.p2canon <- projs.2canon(unit.struct$Q, trt.struct$Q)
efficiencies.p2canon(unit.trt.p2canon)
```

---

efficiency.criteria *Computes efficiency criteria from a set of efficiency factors*

Description

Computes efficiency criteria from a set of efficiency factors.

Usage

```
efficiency.criteria(efficiencies)
```

Arguments

efficiencies	A numeric containing a set of efficiency factors.

Details

The aefficiency criterion is the harmonic mean of the nonzero efficiency factors. The mefficiency criterion is the mean of the nonzero efficiency factors. The eefficiency criterion is the minimum of the nonzero efficiency factors. The sefficiency criterion is the variance of the nonzero efficiency factors. The xefficiency is the maximum of the efficiency factors. The order is the order of balance and is the number of unique nonzero efficiency factors. The dforthog is the number of efficiency factors that are equal to one.

Value

A list whose components are aefficiency, mefficiency, sefficiency, eefficiency, xefficiency, order and dforthog.

Author(s)

Chris Brien

See Also

proj2.efficiency, proj2.eigen, proj2.combine in package **dae**, eigen.

projector for further information about this class.

Examples

```
## PBIBD(2) from p. 379 of Cochran and Cox (1957) Experimental Designs.
## 2nd edn Wiley, New York
PBIBD2.unit <- list(Block = 6, Unit = 4)
PBIBD2.nest <- list(Unit = "Block")
trt <- factor(c(1,4,2,5, 2,5,3,6, 3,6,1,4, 4,1,5,2, 5,2,6,3, 6,3,4,1))
PBIBD2.lay <- designRandomize(allocated = trt,
                              recipient = PBIBD2.unit,
                              nested.recipients = PBIBD2.nest)

## obtain sets of projectors
unit.struct <- pstructure(~ Block/Unit, data = PBIBD2.lay)
trt.struct <- pstructure(~ trt, data = PBIBD2.lay)

## save intrablock efficiencies
eff.inter <- proj2.efficiency(unit.struct$Q[["Unit[Block]"]], trt.struct$Q[["trt"]])

## calculate efficiency criteria
efficiency.criteria(eff.inter)
```

---

elements *Extract the elements of an array specified by the subscripts*

Description

Elements of the array x corresponding to the rows of the two dimensional object subscripts are extracted. The number of columns of subscripts corresponds to the number of dimensions of x. The effect of supplying less columns in subscripts than the number of dimensions in x is the same as for "[".

Usage

```
elements(x, subscripts)
```

Arguments

x	An array with at least two dimensions whose elements are to be extracted.
subscripts	A two dimensional object interpreted as elements by dimensions.

Value

A vector containing the extracted elements and whose length equals the number of rows in the subscripts object.

Author(s)

Chris Brien

See Also

Extract

Examples

```
## Form a table of the means for all combinations of Row and Line.
## Then obtain the values corresponding to the combinations in the data frame x,
## excluding Row 3.
x <- fac.gen(list(Row = 2, Line = 4), each =2)
x$y <- rnorm(16)
RowLine.tab <- tapply(x$y, list(x$Row, x$Line), mean)
xs <- elements(RowLine.tab, subscripts=x[x$"Line" != 3, c("Row", "Line")])
```

Exp249.munit.des *Systematic, main-unit design for an experiment to be run in a greenhouse*

Description

In this main-unit design, there are 24 lanes by 11 Positions, the lanes being blocked into 6 Zones of 4 lanes. The design for the main units is for assigning 75 wheat lines, of which 73 are Nested Association Mapping (NAM) wheat lines and the other two are two check lines, Scout and Gladius. A row and column design was generated with DiGGer (Coombes, 2009). For more details see the vignette accessed via vignette("DesignNotes", package="dae").

Usage

```
data(Exp249.munit.des)
```

Format

A data.frame containing 264 observations of 3 variables.

Source

Coombes, N. E. (2009) Digger*: design search tool in R*. URL: http://nswdpibiom.org/austatgen/software/, (accessed June 3, 2015).

---

extab *Expands the values in table to a vector*

Description

Expands the values in table to a vector according to the index.factors that are considered to index the table, either in standard or Yates order. The order of the values in the vector is determined by the order of the values of the index.factors.

Usage

```
extab(table, index.factors, order="standard")
```

Arguments

table	A numeric vector containing the values to be expanded. Its length must equal the product of the number of used levels for the factors in index.factors and the values in it correspond to all levels combinations of these factors. That is, the values of the index.factors are irrelevant to table.
index.factors	A list of factors that index the table. All the factors must be the same length.
order	The order in which the levels combinations of the index.factors are to be considered as numbered in indexing table; standard numbers them as if they are arranged in standard order, that is with the first factor moving slowest and the last factor moving fastest; yates numbers them as if they are arranged in Yates order, that is with the first factor moving fastest and last factor moving slowest.

Value

A vector of length equal to the factors in index.factor whose values are taken from table.

Author(s)

Chris Brien

Examples

```
## generate a small completely randomized design with the two-level
## factors A and B
n <- 12
CRD.unit <- list(Unit = n)
CRD.treat <- fac.gen(list(A = 2, B = 2), each = 3)
CRD.lay <- designRandomize(allocated = CRD.treat, recipient = CRD.unit,
                           seed = 956)

## set up a 2 x 2 table of A x B effects
AB.tab <- c(12, -12, -12, 12)

## add a unit-length vector of expanded effects to CRD.lay
attach(CRD.lay)
CRD.lay$AB.effects <- extab(table=AB.tab, index.factors=list(A, B))
```

---

fac.ar1mat *forms the ar1 correlation matrix for a (generalized) factor*

Description

Form the correlation matrix for a (generalized) factor where the correlation between the levels follows an autocorrelation of order 1 (ar1) pattern.

Usage

```
fac.ar1mat(factor, rho)
```

Arguments

factor	The (generalized) factor for which the correlation between its levels displays an ar1 pattern.
rho	The correlation parameter for the ar1 process.

Details

The method is: a) form an n x n matrix of all pairwise differences in the numeric values corresponding to the observed levels of the factor by taking the difference between the following two n x n matrices are equal: 1) each row contains the numeric values corresponding to the observed levels of the factor, and 2) each column contains the numeric values corresponding to the observed levels of the factor, b) replace each element of the pairwise difference matrix with rho raised to the absolute value of the difference.

Value

An n x n matrix, where n is the length of the factor.

Author(s)

Chris Brien

See Also

fac.vcmat, fac.meanop, fac.sumop in package **dae**.

Examples

```
## set up a two-level factor and a three-level factor, both of length 12
A <- factor(rep(1:2, each=6))
B <- factor(rep(1:3, each=2, times=2))

## create a 12 x 12 ar1 matrix corrresponding to B
ar1.B <- fac.ar1mat(B, 0.6)
```

---

fac.combine *Combines several factors into one*

Description

Combines several factors into one whose levels are the combinations of the used levels of the individual factors.

Usage

```
fac.combine(factors, order="standard", combine.levels=FALSE, sep=",", ...)
```

Arguments

factors	A list of factors all of the same length.
order	Either standard or yates. The order in which the levels combinations of the factors are to be considered as numbered when forming the levels of the combined factor; standard numbers them as if they are arranged in standard order, that is with the levels of the first factor moving slowest and those of the last factor moving fastest; yates numbers them as if they are arranged in Yates order, that is with the levels of the first factor moving fastest and those of the last factor moving slowest.
combine.levels	A logical specifying whether the levels labels of the new factor are to be combined from those of the factors being combined. The default is to use the integers from 1 to the product of the numbers of combinations of used levels of the individual factors, numbering the levels according to order.
sep	A character string to separate the levels when combine.levels = TRUE.
...	Further arguments passed to the factor call creating the new factor.

Value

A factor whose levels are formed form the observed combinations of the levels of the individual factors.

Author(s)

Chris Brien

See Also

fac.uncombine, fac.split, fac.divide in package **dae**.

Examples

```
## set up two factors
A <- factor(rep(1:2, each=6))
B <- factor(rep(1:3, each=2, times=2))

## obtain six-level factor corresponding to the combinations of A and B
AB <- fac.combine(list(A,B))
```

---

fac.divide *Divides a factor into several separate factors*

Description

Takes a factor and divides it into several separate factors as if the levels in the original combined.factor are numbered from one to its number of levels and correspond to the numbering of the levels combinations of the new factors when these are arranged in standard or Yates order.

Usage

```
fac.divide(combined.factor, factor.names, order="standard")
```

Arguments

combined.factor	A factor that is to be divided into the individual factors listed in factor.names.
factor.names	A list of factors to be formed. The names in the list are the names of the factors and the component of a name is either a) a single numeric value that is the number of levels, b) a numeric vector that contains the levels of the factor, or c) a character vector that contains the labels of the levels of the factor.
order	Either standard or yates. The order in which the levels combinations of the factors in factor.names are to be considered as numbered; standard numbers them as if they are arranged in standard order, that is with the first factor moving slowest and the last factor moving fastest; yates numbers them as if they are arranged in Yates order, that is with the first factor moving fastest and last factor moving slowest.

Value

A data.frame whose columns consist of the factors listed in factor.names and whose values have been computed from the combined factor. All the factors will be of the same length.

Note

A single factor name may be supplied in the list in which case a data.frame is produced that contains the single factor computed from the numeric vector. This may be useful when calling this function from others.

Author(s)

Chris Brien

See Also

fac.split, fac.uncombine, fac.combine in package **dae**.

Examples

```
## generate a small completely randomized design for 6 treatments
n <- 12
CRD.unit <- list(Unit = n)
treat <- factor(rep(1:4, each = 3))
CRD.lay <- designRandomize(allocated = treat, recipient = CRD.unit, seed=956)

## divide the treatments into two two-level factors A and B
CRD.facs <- fac.divide(CRD.lay$treat, factor.names = list(A = 2, B = 2))
```

fac.gen — *Generate all combinations of several factors and, optionally, replicate them*

Description

Generate all combinations of several factors and, optionally, replicate them.

Usage

```
fac.gen(generate, each=1, times=1, order="standard")
```

Arguments

generate	A list of named objects and numbers that specify the factors whose levels are to be generated and the pattern in these levels.If a component of the list is named, then the component should be either a) a single numeric value that is the number of levels, b) a numeric vector that contains the levels of the factor, or c) a character vector that contains the labels of the levels of the factor.
each	The number of times to replicate consecutively the elements of the levels generated according to pattern specified by the generate argument.
times	The number of times to repeat the whole generated pattern of levels generated according to pattern specified by the generate argument.
order	Either standard or yates. The order in which the speed of cycling through the levels is to move; combinations of the factors are to be considered as numbered; standard cycles through the levels of the first factor slowest and the last factor moving fastest; yates cycles through the levels of the first factor fastest and last factor moving slowest.

Details

The levels of each factor are generated in a hierarchical pattern, such as standard order, where the levels of one factor are held constant while those of the adjacent factor are cycled through the complete set once. If a number is supplied instead of a name, the pattern is generated as if a factor with that number of levels had been supplied in the same position as the number. However, no levels are stored for this unamed factor.

Value

A data.frame of factors whose generated levels are those supplied in the generate list. The number of rows in the data.frame will equal the product of the numbers of levels of the supplied factors and the values of the each and times arguments.

Warning

Avoid using factor names F and T as these might be confused with FALSE and TRUE.

Author(s)

Chris Brien

See Also

fac.genfactors , fac.combine in package **dae**

Examples

```
## generate a 2^3 factorial experiment with levels - and +, and
## in Yates order
mp <- c("-", "+")
fnames <- list(Catal = mp, Temp = mp, Press = mp, Conc = mp)
Fac4Proc.Treats <- fac.gen(generate = fnames, order="yates")

## Generate the factors A, B and D. The basic pattern has 4 repetitions
## of the levels of D for each A and B combination and 3 repetitions of
## the pattern of the B and D combinations for each level of A. This basic
## pattern has each combination repeated twice, and the whole of this
## is repeated twice. It generates 864 A, B and D combinations.
gen <- list(A = 3, 3, B = c(0,100,200), 4, D = c("0","1"))
fac.gen(gen, times=2, each=2)
```

---

fac.genfactors *Generate all combinations of the levels of the supplied factors, without replication*

Description

Generate all combinations of the levels of the supplied factors, without replication. This function extracts the levels from the supplied factors and uses them to generate the new factors. On the other hand, the levels must supplied in the generate argument of the function fac.gen.

Usage

```
fac.genfactors(factors, ...)
```

Arguments

factors	A list of factors, or an object of factors that is coercible to a list.
...	Further arguments passed to the fac.gen in creating the data.frame of new factors.

Details

The levels of each factor are generated in standard order, unless order is supplied to fac.gen via the '...' argument. The levels of the new factors will be in the same order as in the supplied factors.

Value

A data.frame whose columns correspond to factors in the factors list. The values in a column are the generated levels of the factor. The number of rows in the data.frame will equal the product of the numbers of levels of the supplied factors.

Author(s)

Chris Brien

See Also

fac.gen in package **dae**

Examples

```
## generate a treatments key for the Variety and Nitrogen treatments factors in Oats.dat
data(Oats.dat)
trts.key <- fac.genfactors(factors = Oats.dat[c("Variety", "Nitrogen")])
trts.key$Treatment <- factor(1:nrow(trts.key))
```

---

fac.match — *Match, for each combination of a set of columns in* x*, the row that has the same combination in* table

---

Description

Match, for each combination of a set of columns in x, the rows that has the same combination in table. The argument multiples.allow controls what happens when there are multple matches in table of a combination in x.

Usage

```
fac.match(x, table, col.names, nomatch = NA_integer_, multiples.allow = FALSE)
```

Arguments

x	an R object, normally a data.frame, possibly a matrix.
table	an R object, normally a data.frame, possibly a matrix.
col.names	A character vector giving the columns in x and table that are to be matched.
nomatch	The value to be returned in the case when no match is found. Note that it is coerced to integer.
multiples.allow	A logical indicating whether multiple matches of a combination in x to those in table is allowed. If multiples.allow is FALSE, an error is generated. If multiples.allow is TRUE, the first occuence in table is matched. This function can be viewed as a generalization to multiple vectors of the match function that applies to single vectors.

Value

A vector of length equal to x that gives the rows in table that match the combinations of col.names in x. The order of the rows is the same as the order of the combintions in x. The value returned if a combination is unmatched is specified in the nomatch argument.

Author(s)

Chris Brien

See Also

match

Examples

```
## Not run:
#A single unmatched combination
kdata <- data.frame(Expt="D197-5",
                    Row=8,
                    Column=20, stringsAsFactors=FALSE)
index <- fac.match(kdata, D197.dat, c("Expt", "Row", "Column"))

# A matched and an unmatched combination
kdata <- data.frame(Expt=c("D197-5", "D197-4"),
                    Row=c(8, 10),
                    Column=c(20, 8), stringsAsFactors=FALSE)
index <- fac.match(kdata, D197.dat, c("Expt", "Row", "Column"))

## End(Not run)
```

---

fac.meanop *computes the projection matrix that produces means*

Description

Computes the symmetric projection matrix that produces the means corresponding to a (generalized) factor.

Usage

```
fac.meanop(factor)
```

Arguments

factor	The (generalized) factor whose means the projection matrix computes from an observation-length vector.

Details

The design matrix **X** for a (generalized) factor is formed with a column for each level of the (generalized) factor, this column being its indicator variable. The projection matrix is formed as X %*% (1/diag(r) %*% t(X), where r is the vector of levels replications.

A generalized factor is a factor formed from the combinations of the levels of several original factors. Generalized factors can be formed using fac.combine.

Value

A projector containing the symmetric, projection matrix and its degrees of freedom.

Author(s)

Chris Brien

See Also

fac.combine, projector, degfree, correct.degfree, fac.sumop in package **dae**.

projector for further information about this class.

Examples

```
## set up a two-level factor and a three-level factor, both of length 12
A <- factor(rep(1:2, each=6))
B <- factor(rep(1:3, each=2, times=2))

## create a generalized factor whose levels are the combinations of A and B
AB <- fac.combine(list(A,B))

## obtain the operator that computes the AB means from a vector of length 12
M.AB <- fac.meanop(AB)
```

`fac.multinested` *Creates several factors, one for each level of nesting.fac and each of whose values are either generated within those of a level of nesting.fac or using the values of nested.fac within a levels of nesting.fac.*

Description

Creates several factors, one for each level of `nesting.fac` and each of whose values are either (i) generated within those of the level of `nesting.fac` or (ii) using the values of `nested.fac` within the levels of the `nesting.fac`. For (i), all elements having the same level of `nesting.fac` are numbered from 1 to the number of different elements having that level. For (ii), the values of `nested.fac` for a level of `nesting.fac` are copied. In both cases, for the values of `nested.fac` not equal to the level of the values of `nested.fac` for which a nested factor is being created, the levels are set to `outlevel` and labelled using `outlabel`. A factor is not created for a level of `nesting.fac` with label equal to `outlabel`. The names of the factors are equal to the levels of `nesting.fac`; optionally `fac.prefix` is added to the beginning of the names of the factors. The function is used to split up a nested term into separate terms for each level of `nesting.fac`.

Usage

```
fac.multinested(nesting.fac, nested.fac = NULL, fac.prefix = NULL,
                nested.levs = NA, nested.labs = NA,
                outlevel = 0, outlabel = "rest", ...)
```

Arguments

`nesting.fac`	The factor for each of whose `levels` a nested facor is to be generated, except one is not generated for the `outlabel` level.
`nested.fac`	The factor whose values for a level are to be used for the factor being created for that level. If `nested.fac` is `NULL`, then the values of the `levels` is the the list of numbers from 1 to the replication of the level of `nesting.fac`, represented as characters.
`fac.prefix`	The prefix to be added to a level in naming a nested factor.

nested.levs	Optional vector of levels for the nested factors. Any data value that does not match a value in nested.levs will be NA in the nested factor being generated. The default value of nested.levs is the list of numbers from 1 to the replication of the levels of nesting.fac, represented as characters. When nested.fac is not NULL, nested.levs is not used.
nested.labs	Optional vector of values to use as labels for the levels of the new nested factors; they are combined with outlabel. The default is as.character(levels).
outlevel	The level to use in the new factor for all values of old factor that do not correspond to the level of the nesting.fac to which the new factor corresponds.
outlabel	The label to use the outlevel level.
...	Further arguments passed to the factor call creating a new factor.

Value

A data.frame containing a factor for each level of nesting.fac.

Note

The levels of nesting.fac do not have to be equally replicated.

Author(s)

Chris Brien

See Also

fac.gen, fac.nested in package **dae**, factor.

Examples

```
lay <- data.frame(A = factor(rep(c(1:3), c(3,6,4)), labels = letters[1:3]))
lay$B <-fac.nested(lay$A)

#Add factors for B within each level of A
lay2 <- cbind(lay, fac.multinested(lay$A))
canon2 <- designAnatomy(list(~A/(a+b+c)), data = lay2)
summary(canon2)

#Add factors for B within each level of A, but with levels and outlabel given
lay2 <- cbind(lay, fac.multinested(lay$A, nested.levs = seq(10,60,10), outlabel = "other"))

canon2 <- designAnatomy(list(~A/(a+b+c)), data = lay2)
summary(canon2)


#Replicate the combinations of A and B three times and index them with the factor sample
lay3 <- rbind(lay,lay,lay)
lay3$sample <- with(lay3, fac.nested(fac.combine(list(A,B))))

#Add factors for B within each level of A
lay4 <- cbind(lay3, fac.multinested(nesting.fac = lay$A, nested.fac = lay$B))

canon4 <- designAnatomy(list(~(A/(a+b+c))/sample), data = lay4)
summary(canon4)
```

```
#Add factors for sample within each combination of A and B
lay5 <- with(lay4, cbind(lay4,
                         fac.multinested(nesting.fac = a, fac.prefix = "a"),
                         fac.multinested(nesting.fac = b, fac.prefix = "b"),
                         fac.multinested(nesting.fac = c, fac.prefix = "c")))

canon5 <- designAnatomy(list(~A/(a/(a1+a2+a3)+b/(b1+b2+b3+b4+b5+b6)+c/(c1+c2+c3))), data = lay5)
summary(canon5)

#Add factors for sample within each level of A
lay6 <- cbind(lay4,
        fac.multinested(nesting.fac = lay4$A, nested.fac = lay$sample, fac.prefix = "samp"))
canon6 <- designAnatomy(list(~A/(a/sampa+b/sampb+c/sampc)), data = lay6)
summary(canon6)
```

`fac.nested` *creates a factor, the nested factor, whose values are generated within those of the factor nesting.fac*

Description

Creates a nested `factor` whose `levels` are generated within those of the factor `nesting.fac`. All elements of `nesting.fac` having the same level are numbered from 1 to the number of different elements having that level.

Usage

```
fac.nested(nesting.fac, nested.levs=NA, nested.labs=NA, ...)
```

Arguments

`nesting.fac`	The `factor` within each of whose `levels` the created `factor` is to be generated.
`nested.levs`	Optional `vector` of levels for the `factor`. Any data value that does not match a value in `levels` will be `NA` in the `factor`. The default value of `nested.levs` is the list of numbers from 1 to the maximum replication of the `levels` of `nesting.fac`, represented as characters.
`nested.labs`	Optional `vector` of values to use as `labels` for the `levels` of the `factor`. The default is `as.character(nested.levs)`.
`...`	Further arguments passed to the `factor` call creating the new `factor`.

Value

A `factor` that is a character `vector` with class attribute "`factor`" and a `levels` attribute which determines what character strings may be included in the `vector`. It has a different level for of the values of the nesting.fac with the same level.

Note

The levels of `nesting.fac` do not have to be equally replicated.

Author(s)

Chris Brien

See Also

fac.gen, fac.multinested in package **dae**, factor.

Examples

```
## set up factor A
A <- factor(c(1, 1, 1, 2, 2))

## create nested factor
B <- fac.nested(A)
```

---

fac.recast — *Recasts a factor by modifying the values in the factor vector and/or the levels attribute, possibly combining some levels into a single level.*

Description

A factor is comprised of a vector of values and a levels attribute. This function can modify these separately or jointly. The newlevels argument recasts both the values of a factor vector and the levels attribute, using each value in the newlevels vector to replace the corresponding value in both factor vector and the levels attribute. The factor, possibly with the new levels, can have its levels attribute reordered and/or new labels associated with the levels using the levels.order and newlabels arguments.

Usage

```
fac.recast(factor, newlevels = NULL, levels.order = NULL, newlabels = NULL, ...)
```

Arguments

factor	The factor to be recast.
newlevels	A vector of length levels(factor) that changes both the values in the factor vector and its levels attribute. The values in the newlevels vector need not be unique, but there must be as many values as there are levels in the supplied factor. The levels in the vector of the supplied factor that have the same value in newlevels will be combined in the recast factor. The values in the new levels attribute can be re-oredered using levels.order.
levels.order	A vector that specifies the order of the levels in the levels attribute of the recast factor. If newlevels is NULL, must be of length levels(factor) and contain the old levels in the new order for the recast factor. If newlevels is not NULL, the vector must be of length(unique(newlevels)) and contain the unique values in newlevels in the new order for the recast factor. The values in the factor vector whose levels are being re-ordered will be unchanged. If levels.order is NULL, then the current levels attribute of factor is used.

newlabels	A vector of length levels(factor) if newlevels is NULL, and of length unique(newlevels) if it is not NULL. It should contain the values to be used as labels in the recast factor. Effectively, this changes the values in the factor vector to those given in newlabels and the levels attribute to newlabels.
...	Further arguments passed to the factor call creating the new factor.

Value

A factor.

Author(s)

Chris Brien

See Also

fac.uselogical, as.numfac and mpone in package **dae**, factor, relevel.

Examples

```
## set up a factor with labels
Treats <- factor(rep(1:4, 4), labels=letters[1:4])

## recast to reduce the levels: "a" and "d" to 1 and "b" and "c" to 2, i.e. from 4 to 2 levels
A <- fac.recast(Treats, newlevels = c(1,2,2,1), labels = letters[1:2])
A <- fac.recast(Treats, newlevels = letters[c(1,2,2,1)])

#reduce the levels from 4 to 2, with re-ordering the levels vector without changing the values
#of the new recast factor vector
A <- fac.recast(Treats, newlevels = letters[c(1,2,2,1)], levels.order = letters[2:1])

#reassign the values in the factor vector without re-ordering the levels attribute
A <- fac.recast(Treats, newlevels = letters[4:1])

#reassign the values in the factor vector, with re-ordering the levels attribute
A <- fac.recast(Treats, newlabels = letters[4:1])

#reorder the levels attribute with changing the values in the factor vector
A <- fac.recast(Treats, levels.order = letters[4:1])

#reorder the values in the factor vector without changing the levels attribute
A <- fac.recast(Treats, newlevels = 4:1, newlabels = levels(Treats))
```

---

fac.recode *Recodes factor* levels *using values in a vector. The values in the vector do not have to be unique.*

Description

Recodes the levels and values of a factor using each value in the newlevels vector to replace the corresponding value in the vector of levels of the factor.

This function has been superseded by fac.recast, which has extended functionality. Calls to fac.recast that use only the factor and newlevels argument will produce the same results as a call to fa.recode. fac.recode may be deprecated in future versions of dae and is being retained for now to maintain backwards compatibility.

Usage

```
fac.recode(factor, newlevels, ...)
```

Arguments

factor	The factor to be recoded.
newlevels	A vector of length levels(factor) containing values to use in the recoding.
...	Further arguments passed to the factor call creating the new factor.

Value

A factor.

Author(s)

Chris Brien

See Also

fac.recast, fac.uselogical, as.numfac and mpone in package **dae**, factor, relevel.

Examples

```
## set up a factor with labels
Treats <- factor(rep(1:4, 4), labels=c("A","B","C","D"))

## recode "A" and "D" to 1 and "B" and "C" to 2
B <- fac.recode(Treats, c(1,2,2,1), labels = c("a","b"))
```

---

fac.split — *Splits a factor whose levels consist of several delimited strings into several factors*

Description

Splits a factor, whose levels consist of strings delimited by a separator character, into several factors. It uses the function strsplit, with fixed = TRUE to split the levels.

Usage

```
fac.split(combined.factor, factor.names, sep=",", ...)
```

Arguments

combined.factor	A factor to be split into several factors.
factor.names	A list of names for factors and associated levels, if required. The names of the components of the list are used for the names of the new factors. Each component of the list should either be NULL or a vector of levels for the new factor. If a component is NULL then the unique values for the supplied factor are used as the levels, which are sorted into alphabetical order. If a either a numeric or a character vector is supplied for a component, then these are supplied as the levels of the new factor.
sep	A character string that separates the levels in the combined.factor.
...	Further arguments passed to the factor call creating the new factor.

Value

A data.frame containing the new factors.

Author(s)

Chris Brien

See Also

fac.divide, fac.uncombine, fac.combine in package **dae** and strsplit.

Examples

```
## Form a combined factor to split
data(Oats.dat)
tmp <- within(Oats.dat, Trts <- fac.combine(list(Variety, Nitrogen), combine.levels = TRUE))

##Variety levels sorted into alphabetical order
trts.dat <- fac.split(combined.factor = tmp$Trts,
                      factor.names = list(Variety = NULL, Nitrogen = NULL))

##Variety levels order from Oats.dat retained
trts.dat <- fac.split(combined.factor = tmp$Trts,
                    factor.names = list(Variety = levels(tmp$Variety), Nitrogen = NULL))
```

---

fac.sumop *computes the summation matrix that produces sums corresponding to a (generalized) factor*

Description

Computes the matrix that produces the sums corresponding to a (generalized) factor.

Usage

```
fac.sumop(factor)
```

Arguments

factor	The (generalized) factor whose sums the summation matrix computes from an observation-length vector.

Details

The design matrix **X** for a (generalized) factor is formed with a column for each level of the (generalized) factor, this column being its indicator variable. The summation matrix is formed as X %*% t(X).

A generalized factor is a factor formed from the combinations of the levels of several original factors. Generalized factors can be formed using fac.combine.

Value

A symmetric matrix.

Author(s)

Chris Brien

See Also

fac.combine, fac.meanop in package **dae**.

Examples

```
## set up a two-level factoir and a three-level factor, both of length 12
A <- factor(rep(1:2, each=6))
B <- factor(rep(1:3, each=2, times=2))

## create a generlaized factor whose levels are the combinations of A and B
AB <- fac.combine(list(A,B))

## obtain the operator that computes the AB means from a vector of length 12
S.AB <- fac.sumop(AB)
```

---

fac.uncombine *Cleaves a single factor, each of whose levels has delimited strings, into several factors using the separated strings.*

Description

Cleaves a single factor into several factors whose levels, the levels of the original factor consisting of several delimited strings that can be separated to form the levels of the new.factors. That is, it reverses the process of combining factors that fac.combine performs.

Usage

```
fac.uncombine(factor, new.factors, sep=",", ...)
```

Arguments

factor	A factor or character that has values that are strings deleimited by the delimiter specified by sep.
new.factors	A list, whose component names are the names of the new factors to be formed. If a component is not NULL, then they are used as the levels of the corresponding factor.
sep	A character string that separates the levels of the new.factors in the levels factor.
...	Further arguments passed to the factor call creating the new factor.

Value

A data.frame whose columns consist of the factors listed in new.factors and whose values have been computed from the values of the combined factor.

Author(s)

Chris Brien

See Also

fac.split, fac.combine, fac.divide in package **dae** and strsplit.

Examples

```
## set up two factors and combine them
facs <- fac.gen(list(A = letters[1:3], B = 1:2), each = 4)
facs$AB <- with(facs, fac.combine(list(A, B), combine.levels = TRUE))

## now reverse the proces and uncombine the two factors
new.facs <- fac.uncombine(factor = facs$AB,
                          new.factors = list(A = letters[1:3], B = NULL),
                          sep = ",")
new.facs <- fac.uncombine(factor = facs$AB,
                          new.factors = list(A = NULL, B = NULL),
                          sep = ",")
```

---

fac.uselogical *Forms a two-level factor from a logical object.*

Description

Forms a two-level factor from a logical object. It can be used to recode a factor when the resulting factor is to have only two levels.

Usage

```
fac.uselogical(x, levels = c(TRUE, FALSE), labels = c("yes", "no"), ...)
```

Arguments

x	A logical vector with values TRUE or FALSE. If the vector is not a logical, as.logical will be used in an attempt to coerce it to logical.
levels	A vector of length two with values TRUE or T and FALSE or F, in either order depending on which of TRUE or FALSE is to be the first level.
labels	A vector of length two with values to be used as labels for the first and second levels, respectively.
...	Further arguments passed to the factor call creating the new factor.

Value

A factor.

Author(s)

Chris Brien

See Also

fac.recast, as.numfac and mpone in package **dae**, factor, relevel.

Examples

```
## set up a factor with labels
Treats <- factor(rep(1:4, 4), labels=c("A","B","C","D"))

## recode "A" and "D" to "a" and "B" and "C" to "b"
B <- fac.uselogical(Treats %in% c("A", "D"), labels = c("a","b"))
B <- fac.uselogical(Treats %in% c("A", "D"), labels = c(-1,1))

## suppose level A in factor a is a control treatment
## set up a factor Control to discriminate between control and treated
Control <- fac.uselogical(Treats == "A")
```

---

fac.vcmat *forms the variance matrix for the variance component of a (generalized) factor*

Description

Form the variance matrix for a (generalized) factor whose effects for its different levels are independently and identically distributed, with their variance given by the variance component; elements of the matrix will equal either zero or sigma2 and displays compound symmetry.

Usage

```
fac.vcmat(factor, sigma2)
```

Arguments

factor	The (generalized) factor for which the variance matrix is required.
sigma2	The variance component, being the of the random effects for the factor.

Details

The method is: a) form the n x n summation or relationship matrix whose elements are equal to zero except for those elements whose corresponding elements in the following two n x n matrices are equal: 1) each row contains the numeric values corresponding to the observed levels of the factor, and 2) each column contains the numeric values corresponding to the observed levels of the factor, b) multiply the summation matrix by sigma2.

Value

An n x n `matrix`, where n is the length of the `factor`.

Author(s)

Chris Brien

See Also

`fac.ar1mat`, `fac.meanop`, `fac.sumop` in package **dae**.

Examples

```
## set up a two-level factor and a three-level factor, both of length 12
A <- factor(rep(1:2, each=6))
B <- factor(rep(1:3, each=2, times=2))

## create a 12 x 12 ar1 matrix corrresponding to B
vc.B <- fac.vcmat(B, 2)
```

Fac4Proc.dat *Data for a 2^4 factorial experiment*

Description

The data set come from an unreplicated 2^4 factorial experiment to investigate a chemical process. The response variable is the Conversion percentage (Conv) and this is indexed by the 4 two-level factors Catal, Temp, Press and Conc, with levels "-" and "+". The data is aranged in Yates order. Also included is the 16-level factor Runs which gives the order in which the combinations of the two-level factors were run.

Usage

```
data(Fac4Proc.dat)
```

Format

A data.frame containing 16 observations of 6 variables.

Source

Table 10.6 of Box, Hunter and Hunter (1978) *Statistics for Experimenters*. New York, Wiley.

`fitted.aovlist` *Extract the fitted values for a fitted model from an aovlist object*

Description

Extracts the fitted values as the sum of the effects for all the fitted terms in the model, stopping at `error.term` if this is specified. It is a method for the generic function `fitted`.

Usage

```
## S3 method for class 'aovlist'
fitted(object, error.term=NULL, ...)
```

Arguments

`object`	An `aovlist` object created from a call to `aov`.
`error.term`	The term from the `Error` function down to which effects are extracted for adding to the fitted values. The order of terms is as given in the ANOVA table. If `error.term` is `NULL` effects are extracted from all `Error` terms.
`...`	Further arguments passed to or from other methods.

Value

A numeric `vector` of fitted values.

Note

Fitted values will be the sum of effects for terms from the model, but only for terms external to any `Error` function. If you want effects for terms in the `Error` function to be included, put them both inside and outside the `Error` function so they are occur twice.

Author(s)

Chris Brien

See Also

`fitted.errors`, `resid.errors`, `tukey.1df` in package **dae**.

Examples

```
## set up data frame for randomized complete block design in Table 4.4 from
## Box, Hunter and Hunter (2005) Statistics for Experimenters. 2nd edn
## New York, Wiley.
RCBDPen.dat <- fac.gen(list(Blend=5, Flask=4))
RCBDPen.dat$Treat <- factor(rep(c("A","B","C","D"), times=5))
RCBDPen.dat$Yield <- c(89,88,97,94,84,77,92,79,81,87,87,
                       85,87,92,89,84,79,81,80,88)

## perform the analysis of variance
RCBDPen.aov <- aov(Yield ~ Blend + Treat + Error(Blend/Flask), RCBDPen.dat)
summary(RCBDPen.aov)
```

```
## two equivalent ways of extracting the fitted values
fit  <- fitted.aovlist(RCBDPen.aov)
fit <- fitted(RCBDPen.aov, error.term = "Blend:Flask")
```

`fitted.errors` *Extract the fitted values for a fitted model*

Description

An alias for the generic function `fitted`. When it is available, the method `fitted.aovlist` extracts the fitted values, which is provided in the **dae** package to cover `aovlist` objects.

Usage

```
## S3 method for class 'errors'
fitted(object, error.term=NULL, ...)
```

Arguments

`object`	An `aovlist` object created from a call to `aov`.
`error.term`	The term from the `Error` function down to which effects are extracted for adding to the fitted values. The order of terms is as given in the ANOVA table. If `error.term` is `NULL` effects are extracted from all `Error` terms.
`...`	Further arguments passed to or from other methods.

Value

A numeric vector of fitted values.

Warning

See `fitted.aovlist` for specific information about fitted values when an `Error` function is used in the call to the `aov` function.

Author(s)

Chris Brien

See Also

`fitted.aovlist`, `resid.errors`, `tukey.1df` in package **dae**.

Examples

```
## set up data frame for randomized complete block design in Table 4.4 from
## Box, Hunter and Hunter (2005) Statistics for Experimenters. 2nd edn
## New York, Wiley.
RCBDPen.dat <- fac.gen(list(Blend=5, Flask=4))
RCBDPen.dat$Treat <- factor(rep(c("A","B","C","D"), times=5))
RCBDPen.dat$Yield <- c(89,88,97,94,84,77,92,79,81,87,87,
                       85,87,92,89,84,79,81,80,88)
```

```
## perform the analysis of variance
RCBDPen.aov <- aov(Yield ~ Blend + Treat + Error(Blend/Flask), RCBDPen.dat)
summary(RCBDPen.aov)

## three equivalent ways of extracting the fitted values
fit  <- fitted.aovlist(RCBDPen.aov)
fit <- fitted(RCBDPen.aov, error.term = "Blend:Flask")
fit <- fitted.errors(RCBDPen.aov, error.term = "Blend:Flask")
```

`get.daeTolerance` *Gets the value of daeTolerance for the package dae*

Description

A function that gets the `vector` of values such that, in **dae** functions, values less than it are considered to be zero.

Usage

```
get.daeTolerance()
```

Value

The `vector` of two values for `daeTolerance`, one named `element.tol` that is used for elements of matrices and a second named `element.eigen` that is used for eigenvalues and quantities based on them, such as efficiency factors.

Author(s)

Chris Brien

See Also

`set.daeTolerance`.

Examples

```
## get daeTolerance.
get.daeTolerance()
```

`harmonic.mean` *Calcuates the harmonic mean.*

Description

A function to calcuate the harmonic mean of a set of nonzero numbers.

Usage

```
harmonic.mean(x)
```

Arguments

x	An object from whose elements the harmonic mean is to be computed.

Details

All the elements of x are tested as being less than daeTolerance, which is initially set to .Machine$double.eps ^ 0.5 (about 1.5E-08). The function set.daeTolerance can be used to change daeTolerance.

Value

A numeric. Returns Inf if x contains a value close to zero

Examples

```
y <- c(seq(0.1,1,0.2))
harmonic.mean(y)
```

---

interaction.ABC.plot *Plots an interaction plot for three factors*

Description

Plots a function (the mean by default) of the response for the combinations of the three factors specified as the x.factor (plotted on the x axis of each plot), the groups.factor (plotted as separate lines in each plot) and the trace.factor (its levels are plotted in different plots). Interaction plots for more than three factors can be produced by using fac.combine to combine all but two of them into a single factor that is specified as the trace.factor.

Usage

```
interaction.ABC.plot(response, x.factor, groups.factor,
       trace.factor,data, fun="mean", title="A:B:C Interaction Plot",
       xlab, ylab, key.title, lwd=4, columns=2, ggplotFuncs = NULL, ...)
```

Arguments

response	A numeric vector containing the response variable from which a function (the mean by default) is computed for plotting on the y-axis.
x.factor	The factor to be plotted on the x-axis of each plot. If the levels are numeric values stored as characters, they will be converted to numeric values for plotting. If they are actually numeric codes for nonnumeric categories and you want them plotted on a discrete scale then you should employ nonumeric codings, such as '-' and '+' or 'N' and 'Y' or something similar.
groups.factor	The factor plotted as separate lines in each plot.
trace.factor	The factor for whose levels there are separate plots.
data	A data.frame containing the three factors and the response.
fun	The function to be computed from the response for each combination of the three factors x.factor, groups.factor and trace.factor. By default, the mean is computed for each combination.
title	Title for plot window. By default it is "A:B:C Interaction Plot".

xlab	Label for the x-axis. By default it is the name of the x.factor.
ylab	Label for the y-axis. By default it is the name of the response.
key.title	Label for the key (legend) to the lines in each plot. By default it is the name of the groups.factor.
lwd	The width of the lines. By default it is 4.
columns	The number of columns for arranging the several plots for the levels of the groups.factor. By default it is 2.
ggplotFuncs	A list, each element of which contains the results of evaluating a ggplot function. It is created by calling the list function with a ggplot function call for each element. These functions are applied in creating the ggplot object.
...	Other arguments that are passed down to ggplot methods.

Value

An object of class "ggplot", which can be plotted using print.

Author(s)

Chris Brien

See Also

fac.combine in package **dae**, interaction.plot.

Examples

```
## Not run:
## plot for Example 14.1 from Mead, R. (1990). The Design of Experiments:
## Statistical Principles for Practical Application. Cambridge,
## Cambridge University Press.
## use ?SPLGrass.dat for details
data(SPLGrass.dat)
interaction.ABC.plot(Main.Grass, x.factor=Period,
                     groups.factor=Spring, trace.factor=Summer,
                     data=SPLGrass.dat,
                     title="Effect of Period, Spring and Summer on Main Grass")

## plot for generated data
## use ?ABC.Interact.dat for data set details
data(ABC.Interact.dat)
## Add standard errors for plotting
## - here data contains a single value for each combintion of A, B and C
## - need to supply name for data twice
ABC.Interact.dat$se <- rep(c(0.5,1), each=4)
interaction.ABC.plot(MOE, A, B, C, data=ABC.Interact.dat,
                     ggplotFunc=list(geom_errorbar(data=ABC.Interact.dat,
                                                   aes(ymax=MOE+se, ymin=MOE-se),
                                                   width=0.2)))

## End(Not run)
```

is.allzero *Tests whether all elements are approximately zero*

Description

A single-line function that tests whether all elements are zero (approximately).

Usage

```
is.allzero(x)
```

Arguments

x	An object whose elements are to be tested.

Details

The mean of the absolute values of the elements of x is tested to determine if it is less than daeTolerance, which is initially set to .Machine$double.eps ^ 0.5 (about 1.5E-08). The function set.daeTolerance can be used to change daeTolerance.

Value

A logical.

Author(s)

Chris Brien

Examples

```
## create a vector of 9 zeroes and a one
y <- c(rep(0,9), 1)

## check that vector is only zeroes is FALSE
is.allzero(y)
```

is.projector *Tests whether an object is a valid object of class projector*

Description

Tests whether an object is a valid object of class "projector".

Usage

```
is.projector(object)
```

Arguments

object	The matrix to be made into a projector.

Details

The function is.projector tests whether the object consists of a matrix that is square, symmetric and idempotent. In checking symmetry and idempotency, the equality of the matrix with either its transpose or square is tested. In this, a difference in elements is considered to be zero if it is less than daeTolerance, which is initially set to .Machine$double.eps ^ 0.5 (about 1.5E-08). The function set.daeTolerance can be used to change daeTolerance.

Value

TRUE or FALSE depending on whether the object is a valid object of class "projector".

Warning

The degrees of freedom are not checked. correct.degfree can be used to check them.

Author(s)

Chris Brien

See Also

projector, correct.degfree in package **dae**.

projector for further information about this class.

Examples

```
## set up a 2 x 2 mean operator that takes the mean of a vector of 2 values
m <- matrix(rep(0.5,4), nrow=2)

## create an object of class projector
proj.m <- projector(m)

## check that it is a valid projector
is.projector(proj.m)
```

LatticeSquare_t49.des *A Lattice square design for 49 treatments*

Description

The systematic design for a lattice square for 49 treatments consisting of four 7 x 7 squares. For more details see the vignette accessed via vignette("DesignNotes", package="dae").

Usage

```
data(LatticeSquare_t49.des)
```

Format

A data.frame containing 196 observations of 4 variables.

Source

Cochran and Cox (1957) *Experimental Designs*. 2nd edn Wiley, New York.

`marginality` *Extracts the marginality matrix (matrices) from a* `pstructure.object` *or a* `pcanon.object`.

Description

Produces (i) a marginality `matrix` for the `formula` in a call to `pstructure.formula` or (ii) a `list` containing the marginlity matrices, one for each `formula` in the `formulae` argument of a call to `designAnatomy`.

A marginality matrix for a set of terms is a square `matrix` with a row and a column for each ternon-aliased term. Its elements are zeroes and ones, the entry in the ith row and jth column indicates whether or not the ith term is marginal to the jth term i.e. the column space of the ith term is a subspace of that for the jth term and so the source for the jth term will be orthogonal to that for the ith term.

Usage

```
## S3 method for class 'pstructure'
marginality(object, ...)
## S3 method for class 'pcanon'
marginality(object, ...)
```

Arguments

`object`	A `pstructure.object` produced by `pstructure.formula` or `pcanon.object` produced by `designAnatomy`.
`...`	Further arguments passed to or from other methods. Unused at present.

Value

If `object` is a `pstructure.object` then a `matrix` containing the marginality matrix for the terms obtained from the `formuula` in the call to `pstructure.formula`.

If `object` is a `pcanon.object` then a `list` with a component for each `formula`, each component having a marginality matrix that corresponds to one of the formulae in the call to `designAnatomy`. The components of the `list` will have the same names as the componeents of the `formulae` `list` and so will be unnamed if the components of the latter `list` are unnamed.

Author(s)

Chris Brien

See Also

`pstructure.formula`, `designAnatomy`, `summary.pcanon`, `proj2.efficiency`, `proj2.combine`, `proj2.eigen`,
`pstructure` in package **dae**, `eigen`.

`projector` for further information about this class.

Examples

```
## PBIBD(2) from p. 379 of Cochran and Cox (1957) Experimental Designs.
## 2nd edn Wiley, New York
PBIBD2.unit <- list(Block = 6, Unit = 4)
PBIBD2.nest <- list(Unit = "Block")
trt <- factor(c(1,4,2,5, 2,5,3,6, 3,6,1,4, 4,1,5,2, 5,2,6,3, 6,3,4,1))
PBIBD2.lay <- designRandomize(allocated = trt,
                              recipient = PBIBD2.unit,
                              nested.recipients = PBIBD2.nest)

##obtain pstructure.object and extract marginality matrix
unit.struct <- pstructure(~ Block/Unit, data = PBIBD2.lay)
unit.marg <- marginality(unit.struct)

##obtain combined decomposition and extract marginality matrices
unit.trt.canon <- designAnatomy(list(unit=~ Block/Unit, trt=~ trt), data = PBIBD2.lay)
marg <- marginality(unit.trt.canon)
```

`mat.ar1` *Forms an ar1 correlation matrix*

Description

Form the correlation `matrix` of order `order` whose correlations follow the ar1 pattern. The `matrix` is banded and has diagonal elements equal to one and the off-diagonal element in the ith row and jth column equal to ρ^k where $k = |i - j|$.

Usage

```
mat.ar1(rho, order)
```

Arguments

`rho`	The correlation on the first off-diagonal.
`order`	The order of the `matrix` to be formed.

Value

A banded correlation `matrix` whose elements follow an ar1 pattern.

Author(s)

Chris Brien

See Also

`mat.I`, `mat.J`, `mat.cor`, `mat.corg`, `mat.exp`, `mat.gau`, `mat.banded`, `mat.ar2`, `mat.ar3`, `mat.sar2`, `mat.ma1`, `mat.ma2`, `mat.arma`

Examples

```
corr <- mat.ar1(rho=0.4, order=4)
```

mat.ar2 *Forms an ar2 correlation matrix*

Description

Form the correlation matrix of order order whose correlations follow the ar2 pattern. The resulting matrix is banded.

Usage

```
mat.ar2(ARparameters, order)
```

Arguments

ARparameters	A numeric containing the two autoregressive parameter values of the process, being the weights given to the lag 1 and lag 2 response values.
order	The order of the matrix to be formed.

Details

The correlations in the correlation matrix, corr say, are calculated from the autoregressive parameters, ARparameters. The values in

- the diagonal (k = 1) of corr are one;
- the first subdiagonal band (k = 2) of corr are equal to ARparameters[1]/(1-ARparameters[2]);
- in subsequent disgonal bands, (k = 3:order), of corr are ARparameters[1]*corr[k-1] + ARparameters[2]*corr[k-2].

Value

A banded correlation matrix whose elements follow an ar2 pattern.

Author(s)

Chris Brien

See Also

mat.I, mat.J, mat.cor, mat.corg, mat.exp, mat.gau, mat.banded, mat.ar1, mat.ar3, mat.sar2, mat.ma1, mat.ma2, mat.arma

Examples

```
corr <- mat.ar2(ARparameters = c(0.4, 0.2), order = 4)
```

mat.ar3 *Forms an ar3 correlation matrix*

Description

Form the correlation matrix of order order whose correlations follow the ar3 pattern. The resulting matrix is banded.

Usage

```
mat.ar3(ARparameters, order)
```

Arguments

ARparameters	A numeric containing the three autoregressive parameter values of the process, being the weights given to the lag 1, lag 2 and lag 3 response values.
order	The order of the matrix to be formed.

Details

The correlations in the correlation matrix, corr say, are calculated from the autoregressive parameters, ARparameters.
Let omega = 1 - ARparameters[2] - ARparameters[3] * (ARparameters[1] + ARparameters[3]).
Then the values in

- the diagonal of corr (k = 1) are one;
- the first subdiagonal band (k = 2) of corr are equal to (ARparameters[1] + ARparameters[2]*ARparameters[3]) / omega;
- the second subdiagonal band (k = 3) of corr are equal to (ARparameters[1] * (ARparameters[1] + ARparameters[3]) + ARparameters[2] * (1 - ARparameters[2])) / omega;
- the subsequent subdiagonal bands, (k = 4:order), of corr are equal to ARparameters[1]*corr[k-1] + ARparameters[2]*corr[k-2] + ARparameters[3]*corr[k-3].

Value

A banded correlation matrix whose elements follow an ar3 pattern.

Author(s)

Chris Brien

See Also

mat.I, mat.J, mat.cor, mat.corg, mat.banded, mat.exp, mat.gau, mat.ar1, mat.ar2, mat.sar2, mat.ma1, mat.ma2, mat.arma

Examples

```
corr <- mat.ar3(ARparameters = c(0.4, 0.2, 0.1), order = 4)
```

mat.arma *Forms an arma correlation matrix*

Description

Form the correlation matrix of order order whose correlations follow the arma pattern. The resulting matrix is banded.

Usage

```
mat.arma(ARparameter, MAparameter, order)
```

Arguments

ARparameter	A numeric value for the autoregressive parameter of the process, being the weight given to the lag 1 response values.
MAparameter	A numeric value for the moving average parameter of the process, being the weight given to the lag 1 random variable.
order	The order of the matrix to be formed.

Details

The correlations in the correlation matrix, corr say, are calculated from the correlation parameters, ARparameters. The values in

- the diagonal (k = 1) of corr are one;
- the first subdiagonal band (k = 2) of corr are equal to ARparameters[1]/(1-ARparameters[2]);
- in subsequent disgonal bands, (k = 3:order), of corr are ARparameters[1]*corr[k-1] + ARparameters[2]*corr[k-2].

Value

A banded correlation matrix whose elements follow an arma pattern.

Author(s)

Chris Brien

See Also

mat.I, mat.J, mat.cor, mat.corg, mat.exp, mat.gau, mat.banded, mat.ar1, mat.ar3, mat.sar2, mat.ma1, mat.ma2

Examples

```
corr <- mat.arma(ARparameter = 0.4, MAparameter = -0.2, order = 4)
```

`mat.banded` *Form a banded matrix from a vector of values*

Description

Takes the first value in `x` and places it down the diagonal of the `matrix`. Takes the second value in `x` and places it down the first subdiagonal, both below and above the diagonal of the `matrix`. The third value is placed in the second subdiagonal and so on, until the bands for which there are elements in `x` have been filled. All other elements in the `matrix` will be zero.

Usage

```
mat.banded(x, nrow, ncol)
```

Arguments

`x`	A `numeric` containing the values for each band from 1 to the length of `x`.
`nrow`	The number of rows in the banded `matrix` being formed.
`ncol`	The number of columns in the banded `matrix` being formed.

Value

An $nrow \times ncol$ `matrix`.

Author(s)

Chris Brien

See Also

`mat.cor`, `mat.corg`, `mat.ar1`, `mat.ar2`, `mat.ar3`, `mat.sar2`, `mat.exp`, `mat.gau`, `mat.ma1`, `mat.ma2`, `mat.arma` `mat.I`, `mat.J`

Examples

```
m <- mat.banded(c(1,0.6,0.5), 5,5)
m <- mat.banded(c(1,0.6,0.5), 3,4)
m <- mat.banded(c(1,0.6,0.5), 4,3)
```

mat.cor — *Forms a correlation matrix in which all correlations have the same value.*

Description

Form the correlation matrix of order order in which all correlations have the same value.

Usage

```
mat.cor(rho, order)
```

Arguments

rho	A numeric containing the single correlation value.
order	The order of the correlation matrix to be formed.

Value

A correlation matrix.

Author(s)

Chris Brien

See Also

mat.I, mat.J, mat.corg, mat.banded, mat.exp, mat.gau, mat.ar1, mat.ar2, mat.sar2, mat.ma1, mat.ma2, mat.arma

Examples

```
corr <- mat.cor(rho = 0.4, order = 3)
```

mat.corg — *Forms a general correlation matrix*

Description

Form the correlation matrix of order order for which all correlations potentially differ.

Usage

```
mat.corg(rhos, order, byrow = FALSE)
```

Arguments

rhos	A numeric containing the p(p -1)/2 correlation values ordered either by columns (if byrow is FALSE) or by rows (if byrow is TRUE).
order	The order of the correlation matrix to be formed.
byrow	A logical. If FALSE the lower-traingle of the matrix is filled by columns, otherwise the the ower triangle is filled by rows.

Value

A correlation matrix.

Author(s)

Chris Brien

See Also

mat.I, mat.J, mat.cor, mat.banded, mat.exp, mat.gau, mat.ar1, mat.ar2, mat.sar2, mat.ma1, mat.ma2, mat.arma

Examples

```
corr <- mat.corg(rhos = c(0.4, 0.2, 0.1), order = 3)
```

---

mat.dirprod *Forms the direct product of two matrices*

Description

Form the direct product of the $m \times n$ matrix **A** and the $p \times q$ matrix **B**. It is also called the Kroneker product and the right direct product. It is defined to be the result of replacing each element of **A**, a_{ij}, with $a_{ij}\boldsymbol{B}$. The result matrix is $mp \times nq$.

The method employed uses the rep function to form two $mp \times nq$ matrices: (i) the direct product of **A** and **J**, and (ii) the direct product of **J** and **B**, where each **J** is a matrix of ones whose dimensions are those required to produce an $mp \times nq$ matrix. Then the elementwise product of these two matrices is taken to yield the result.

Usage

```
mat.dirprod(A, B)
```

Arguments

A	The left-hand matrix in the product.
B	The right-hand matrix in the product.

Value

An $mp \times nq$ matrix.

Author(s)

Chris Brien

See Also

matmult, mat.dirprod

Examples

```
col.I <- mat.I(order=4)
row.I <- mat.I(order=28)
V <- mat.dirprod(col.I, row.I)
```

`mat.dirsum` *Forms the direct sum of a list of matrices*

Description

The direct sum is the partitioned matrices whose diagonal submatrices are the matrices from which the direct sum is to be formed and whose off-diagonal submatrices are conformable matrices of zeroes. The resulting `matrix` is $m \times n$, where m is the sum of the numbers of rows of the contributing matrices and n is the sum of their numbers of columns.

Usage

```
mat.dirsum(matrices)
```

Arguments

`matrices`	A list, each of whose component is a `matrix`.

Value

An $m \times n$ `matrix`.

Author(s)

Chris Brien

See Also

`mat.dirprod`, `matmult`

Examples

```
m1 <- matrix(1:4, nrow=2)
m2 <- matrix(11:16, nrow=3)
m3 <- diag(1, nrow=2, ncol=2)
dsum <- mat.dirsum(list(m1, m2, m3))
```

mat.exp *Forms an exponential correlation matrix*

Description

Form the correlation matrix of order equal to the length of coordinates. The matrix has diagonal elements equal to one and the off-diagonal element in the ith row and jth column equal to ρ^k where $k = |coordinate[i] - coordinate[j]|$.

Usage

```
mat.exp(rho, coordinates)
```

Arguments

rho	The correlation for points a distance of one apart.
coordinates	The coordinates of points whose correlation matrix is to be formed.

Value

A correlation matrix whose elements depend on the power of the absolute distance apart.

Author(s)

Chris Brien

See Also

mat.I, mat.J, mat.cor, mat.corg, mat.banded, mat.ar1, mat.ar2, mat.ar3, mat.sar2, mat.ma1, mat.ma2, mat.arma, mat.gau

Examples

```
corr <- mat.exp(coordinates=c(3:6, 9:12, 15:18), rho=0.1)
```

mat.gau *Forms an exponential correlation matrix*

Description

Form the correlation matrix of order equal to the length of coordinates. The matrix has diagonal elements equal to one and the off-diagonal element in the ith row and jth column equal to ρ^k where $k = (coordinate[i] - coordinate[j])^2$.

Usage

```
mat.gau(rho, coordinates)
```

Arguments

rho	The correlation for points a distance of one apart.
coordinates	The coordinates of points whose correlation matrix is to be formed.

Value

A correlation matrix whose elements depend on the power of the absolute distance apart.

Author(s)

Chris Brien

See Also

mat.I, mat.J, mat.cor, mat.corg, mat.banded, mat.ar1, mat.ar2, mat.ar3, mat.sar2, mat.ma1, mat.ma2, mat.arma, mat.exp

Examples

```
corr <- mat.gau(coordinates=c(3:6, 9:12, 15:18), rho=0.1)
```

---

mat.ginv *Computes the generalized inverse of a matrix*

Description

Computes the Moore-Penrose generalized invers of a matrix.

Usage

```
mat.ginv(x, tol = .Machine$double.eps ^ 0.5)
```

Arguments

x	A matrix whose generalized inversed is to be computed.
tol	A numeric specifying the relative tolerance to determine whether an eigenvalue of x is nonzero.

Value

A matrix.

Author(s)

Chris Brien

Examples

```
## PBIBD(2) from p. 379 of Cochran and Cox (1957) Experimental Designs.
## 2nd edn Wiley, New York
PBIBD2.unit <- list(Block = 6, Unit = 4)
PBIBD2.nest <- list(Unit = "Block")
trt <- factor(c(1,4,2,5, 2,5,3,6, 3,6,1,4, 4,1,5,2, 5,2,6,3, 6,3,4,1))
PBIBD2.lay <- designRandomize(allocated = trt,
                              recipient = PBIBD2.unit,
                              nested.recipients = PBIBD2.nest)
## Compute the projector for a linear trend across Blocks
PBIBD2.lay <- within(PBIBD2.lay,
                     {
                       cBlock <- as.numfac(Block)
                       cBlock <- cBlock - mean(unique(cBlock))
                     })
X <- model.matrix(~ cBlock, data = PBIBD2.lay)
Q.cB <- projector((X %*% mat.ginv(t(X) %*% X) %*% t(X)))
```

`mat.I` *Forms a unit matrix*

Description

Form the unit or identity `matrix` of order `order`.

Usage

```
mat.I(order)
```

Arguments

`order`	The order of the `matrix` to be formed.

Value

A square `matrix` whose diagonal elements are one and its off-diagonal are zero.

Author(s)

Chris Brien

See Also

`mat.J`, `mat.ar1`

Examples

```
col.I <- mat.I(order=4)
```

mat.J *Forms a square matrix of ones*

Description

Form the square matrix of ones of order order.

Usage

```
mat.J(order)
```

Arguments

order	The order of the matrix to be formed.

Value

A square matrix all of whose elements are one.

Author(s)

Chris Brien

See Also

mat.I, mat.ar1

Examples

```
col.J <- mat.J(order=4)
```

mat.ma1 *Forms an ma1 correlation matrix*

Description

Form the correlation matrix of order order whose correlations follow the ma1 pattern. The matrix is banded and has diagonal elements equal to one and subdiagonal element equal to -MAparameter / (1 + MAparameter*MAparameter).

Usage

```
mat.ma1(MAparameter, order)
```

Arguments

MAparameter	The moving average parameter, being the weight applied to the lag 1 random pertubation.
order	The order of the matrix to be formed.

Value

A banded correlation matrix whose elements follow an ma1 pattern.

Author(s)

Chris Brien

See Also

mat.I, mat.J, mat.cor, mat.corg, mat.exp, mat.gau, mat.banded, mat.ar2, mat.ar3, mat.sar2, mat.ma2, mat.arma

Examples

```
corr <- mat.ma1(MAparameter=0.4, order=4)
```

---

mat.ma2 *Forms an ma2 correlation matrix*

Description

Form the correlation matrix of order order whose correlations follow the ma2 pattern. The resulting matrix is banded.

Usage

```
mat.ma2(MAparameters, order)
```

Arguments

MAparameters	A numeric containing the two moving average parameter values of the process, being the weights given to the lag 1 and lag 2 random pertubations.
order	The order of the matrix to be formed.

Details

The correlations in the correlation matrix, corr say, are calculated from the moving average parameters, MAparameters. The values in

- the diagonal (k = 1) of corr are one;
- the first subdiagonal band (k = 2) of corr are equal to -MAparameters[1]*(1 - MAparameters[2]) / div;
- the second subdiagonal bande (k = 3) of corr are equal to -MAparameters[2] / div;
- in subsequent disgonal bands, (k = 4:order), of corr are zero,

where div = 1 + MMAparameters[1]*MAparameter[1] + MAparameters[2]*MAparameters[2].

Value

A banded correlation matrix whose elements follow an ma2 pattern.

Author(s)

Chris Brien

See Also

mat.I, mat.J, mat.cor, mat.corg, mat.exp, mat.gau, mat.banded, mat.ar1, mat.ar3, mat.sar2, mat.ma1, mat.arma

Examples

```
corr <- mat.ma2(MAparameters = c(0.4, -0.2), order = 4)
```

---

mat.ncssvar *Calculates the variance matrix of the random effects for a natural cubic smoothing spline*

Description

Calculates the variance matrix of the random effects for a natural cubic smoothing spline. It is the tri-diagonal matrix $\boldsymbol{G}_s$ given by Verbyla et al., (1999) multiplied by the variance component for the random spline effects.

Usage

```
mat.ncssvar(sigma2s = 1, knot.points, print = FALSE)
```

Arguments

sigma2s	A numeric giving the value of the variance component for the random spline effects. The smoothing parameter is then the inverse of the ratio of this component to the residual variance.
knot.points	A numeric giving the values of the knots point used in fitting the spline. These must be orderd in increasing order.
print	A logical indicating whether to print the matrix.

Value

A matrix containing the variances and covariances of the random spline effects.

Author(s)

Chris Brien

References

Verbyla, A. P., Cullis, B. R., Kenward, M. G., and Welham, S. J. (1999). The analysis of designed experiments and longitudinal data by using smoothing splines (with discussion). *Journal of the Royal Statistical Society, Series C (Applied Statistics)*, **48**, 269-311.

See Also

Zncsspline.

Examples

```
Gs <- mat.ncssvar(knot.points = 1:10)
```

`mat.random` *Calculates the variance matrix for the random effects from a mixed model, based on a supplied formula or a matrix.*

Description

For n observations, compute the variance matrix of the random effects. The `matrix` can be specified using a `formula` for the `random` effects and a `list` of values of the variance components for the terms specified in the `random` `formula`. If a `matrix` specifying the variances of the nuisance random effects is supplied then it is returned as the value from the function.

Usage

```
mat.random(random, G, design, keep.order = TRUE)
```

Arguments

`random`	A `formula` or a `matrix`. If a `formula`, it specifies the random effects from which the `matrix` for the contribution of the random effects to the variance matrix can be generated. If it is a `matrix`, it must be an n x n `matrix` and will be passed through as the required variance matrix for the random effects. The default is 0, which implies that there are no random effects.
`G`	This term only needs to be set if `random` is a `formula`. Then it is set to a `list`, in which each component is either a single value or a `matrix`; there needs to be a component for each term in the expanded `formula`, with the order of the terms and components matching. If it is a single value, a diagonal matrix of dimension equal to the product of the numbers of levels of the factors in its term. If it is a matrix, its dimension must be equal to the product of the numbers of levels of the factors in its term.
`design`	A `data.frame` containing the design to be used in an experiment and for which the variane matrix is required. It is not required when the only `formula` specified is an intercept-only `formula`.
`keep.order`	A `logical` indicating whether the terms should keep their position in the expanded `formula` projector, or reordered so that main effects precede two-factor interactions, which precede three-factor interactions and so on.

Details

If $\boldsymbol{Z}_i$ is the is incidence matrix for the `random` nuisance effects in $\boldsymbol{u}_i$ for a term in `random` and $\boldsymbol{u}_i$ has variance matrix $\boldsymbol{G}_i$ so that the contribution of the random effectst to the variance matrix for $\boldsymbol{Y}$ is $\boldsymbol{V}_u = \Sigma(\boldsymbol{Z}_i \boldsymbol{G}_i (\boldsymbol{Z}_i)^T)$.

Value

A n x n `matrix` containing the variance matrix for the random effects.

Author(s)

Chris Brien

See Also

mat.Vpredicts.

Examples

```
## Reduced example from Smith et al. (2015)
## Generate two-phase design
mill.fac <- fac.gen(list(Mrep = 2, Mday = 2, Mord = 3))
field.lay <- fac.gen(list(Frep = 2, Fplot = 4))
field.lay$Variety <- factor(c("D","E","Y","W","G","D","E","M"),
                            levels = c("Y","W","G","M","D","E"))
start.design <- cbind(mill.fac, field.lay[c(3,4,5,8,1,7,3,4,5,8,6,2),])
rownames(start.design) <- NULL

## Set gammas
terms <- c("Variety", "Frep", "Frep:Fplot", "Mrep", "Mrep:Mday", "Mrep:Mday:Mord")
gammas <- c(1, 0.1, 0.2, 0.3, 0.2, 1)
names(gammas) <- terms

## Specify matrices to calculate the variance matrix of the predicted fixed Variety effects
Vu <- with(start.design, fac.vcmat(Mrep, gammas["Mrep"]) +
                         fac.vcmat(fac.combine(list(Mrep,Mday)), gammas["Mrep:Mday"]) +
                         fac.vcmat(Frep, gammas["Frep"]) +
                         fac.vcmat(fac.combine(list(Frep,Fplot)), gammas["Frep:Fplot"]))

## Calculate the variance matrix of the predicted random Variety effects using formulae
Vu <- mat.random(random = ~ -1 + Mrep/Mday + Frep/Fplot,
                 G = as.list(gammas[c(4,5,2,3)]),
                 design = start.design)
```

---

mat.sar *Forms an sar correlation matrix*

Description

Form the correlation matrix of order order whose correlations follow the sar pattern. The resulting matrix is banded.

Usage

```
mat.sar(SARparameter, order)
```

Arguments

SARparameter	A numeric containing the single value of the parameter from which the correlations are calculated.
order	The order of the matrix to be formed.

Details

The values of the correlations in the correlation matrix, `corr` say, are calculated from the SARparameter, gamma as follows. The values in

- the diagonal of `corr` (`k = 1`) are one;
- the first subdiagonal band (`k = 2`) of `corr` are equal to `gamma/(1 + (gamma * gamma / 4))`;
- the subsequent subdiagonal bands, (`k = 3:order`), of `corr` are equal to `gamma * corr[k-1] - (gamma * gamma/4) * corr[k-2]`.

Value

A banded correlation `matrix` whose elements follow an sar pattern.

Author(s)

Chris Brien

See Also

`mat.I`, `mat.J`, `mat.cor`, `mat.corg`, `mat.banded`, `mat.exp`, `mat.gau`, `mat.ar1`, `mat.ar2`, `mat.ar3`, `mat.sar2`, `mat.ma1`, `mat.ma2`, `mat.arma`

Examples

```
corr <- mat.sar(SARparameter = -0.4, order = 4)
```

---

mat.sar2 *Forms an sar2 correlation matrix*

Description

Form the correlation `matrix` of order `order` whose correlations follow the sar2 pattern, a pattern used in crop competition models. The resulting `matrix` is banded and is a constrained AR3 matrix.

Usage

```
mat.sar2(gamma, order, print = NULL)
```

Arguments

`gamma`	A `numeric` containing the two values of `gamma`, being parameters linked with spatial dependence and competition.
`order`	The order of the `matrix` to be formed.
`print`	A `character` giving the object to be printed. Currently, only the claculated values of the `ar3parameters` can be printed. If NULL, nothing is printed.

Details

The values of the AR3 parameters, phi, are calculated from the gammas as follows: `phi[1] = gamma[1] + 2 * gamma[2]`; `phi[2] = -gamma[2] * (2*gamma[2] + gamma[1])`; `phi[3] = gamma[1] * gamma[2] * gamma[2]`.

Then the correlations in the correlation matrix, `corr` say, are calculated from the correlation parameters, phi. Let `omega = 1 - phi[2] - phi[3] * (phi[1] + phi[3])`. Then the values in

- the diagonal of `corr` (`k = 1`) are one;
- the first subdiagonal band (`k = 2`) of `corr` are equal to `(phi[1] + phi[2]*phi[3]) / omega`;
- the second subdiagonal band (`k = 3`) of `corr` are equal to `(phi[1] * (phi[1] + phi[3]) + phi[2] * (1 - phi[2])) / omega`;
- the subsequent subdiagonal bands, (`k = 4:order`), of `corr` are equal to `phi[1]*corr[k-1] + phi[2]*corr[k-2] + phi[3]*corr[k-3]`.

Value

A banded correlation `matrix` whose elements follow an sar2 pattern.

Author(s)

Chris Brien

See Also

`mat.I`, `mat.J`, `mat.cor`, `mat.corg`, `mat.banded`, `mat.exp`, `mat.gau`, `mat.ar1`, `mat.ar2`, `mat.ar3`, `mat.sar`, `mat.ma1`, `mat.ma2`, `mat.arma`

Examples

```
corr <- mat.sar2(gamma = c(-0.4, 0.2), order = 4)
corr <- mat.sar2(gamma = c(-0.4, 0.2), order = 4, print = "ar3")
```

---

mat.Vpred — *Calculates the variances of a set of predicted effects from a mixed model*

Description

For `n` observations, `w` effects to be predicted, `f` nuiscance fixed effects and `r` nuisance random effects, the variances of a set of predicted effects is calculated using the incidence matrix for the effects to be predicted and, optionally, a variance matrix of the effects, an incidence matrix for the nuisance fixed factors and covariates, the variance matrix of the nuisance random effects in the mixed model and the residual variance matrix.

This function has been superseded by `mat.Vpredicts`, which allows the use of both matrices and `formula`e.

Usage

```
mat.Vpred(W, Gg = 0, X = matrix(1, nrow = nrow(W), ncol = 1), Vu = 0, R, eliminate)
```

Arguments

W	The n x w incidence matrix for the w effects to be predicted.
Gg	The w x w variance matrix of the w effects to be predicted. If the effects to be predicted are fixed, set to 0.
X	The n x f incidence matrix for the f nuisance fixed factors and covariates. The default is a column vector of ones.
Vu	The n x r variance matrix of the r nuisance random effects. If there are none, set to zero.
R	The residual variance matrix.
eliminate	The n x n projector onto the subspace corresponding to the effects to be eliminated from the information matrix prior to inverting it to form the variance matrix of the predicted effects. It is only appropriate to use this option when the effects to be predicted are fixed.

Details

Firstly the information matrix is calculated as
`A <- t(W) %*% Vinv %*% W + ginv(Gg) - A%*%ginv(t(X)%*%Vinv%*%X)%*%t(A)`, where `Vinv <- ginv(Vu + R)`, `A = t(W) %*% Vinv %*% X` and ginv(B) is the unique Moore-Penrose inverse of B formed using the eigendecomposition of B.

If `eliminate` is set and the effects to be predicted are fixed then the reduced information matrix is calculated as `A <- (I - eliminate) Vinv (I - eliminate)`.

Finally, the variance of the predicted effects is calculated: `Vpred <- ginv(A)`.

Value

A w x w matrix containing the variances and covariances of the predicted effects.

Author(s)

Chris Brien

References

Smith, A. B., D. G. Butler, C. R. Cavanagh and B. R. Cullis (2015). Multi-phase variety trials using both composite and individual replicate samples: a model-based design approach. *Journal of Agricultural Science*, **153**, 1017-1029.

See Also

designAmeasures, mat.Vpredicts.

Examples

```
## Reduced example from Smith et al. (2015)
## Generate two-phase design
mill.fac <- fac.gen(list(Mrep = 2, Mday = 2, Mord = 3))
field.lay <- fac.gen(list(Frep = 2, Fplot = 4))
field.lay$Variety <- factor(c("D","E","Y","W","G","D","E","M"),
                            levels = c("Y","W","G","M","D","E"))
start.design <- cbind(mill.fac, field.lay[c(3,4,5,8,1,7,3,4,5,8,6,2),])
rownames(start.design) <- NULL
```

```
## Set up matrices
n <- nrow(start.design)
W <- model.matrix(~ -1+ Variety, start.design)
ng <- ncol(W)
Gg<- diag(1, ng)
Vu <- with(start.design, fac.vcmat(Mrep, 0.3) +
                         fac.vcmat(fac.combine(list(Mrep, Mday)), 0.2) +
                         fac.vcmat(Frep, 0.1) +
                         fac.vcmat(fac.combine(list(Frep, Fplot)), 0.2))
R <- diag(1, n)

## Calculate the variance matrix of the predicted random Variety effects
Vp <- mat.Vpred(W = W, Gg = Gg, Vu = Vu, R = R)
designAmeasures(Vp)

## Calculate the variance matrix of the predicted fixed Variety effects,
## elminating the grand mean
Vp.reduc <- mat.Vpred(W = W, Gg = 0, Vu = Vu, R = R,
                      eliminate = projector(matrix(1, nrow = n, ncol = n)/n))
designAmeasures(Vp.reduc)
```

`mat.Vpredicts` *Calculates the variances of a set of predicted effects from a mixed model, based on supplied matrices or formulae.*

Description

For `n` observations, `w` effects to be predicted, `f` nuiscance fixed effects, `r` nuisance random effects and `n` residuals, the variances of a set of predicted effects is calculated using the incidence matrix for the effects to be predicted and, optionally, a variance matrix of these effects, an incidence matrix for the nuisance fixed factors and covariates, the variance matrix of the nuisance random effects and the residual variance matrix. The `matrices` can be supplied directly or using `formula`e and a `matrix` specifying the variances of the nuisance random effects. The difference between `mat.Vpredicts` and `mat.Vpred` is that the former has different names for equivalent arguments and the latter does not allow for the use of `formula`e.

Usage

```
mat.Vpredicts(target, Gt = 0, fixed = ~ 1, random, G, R, design,
              eliminate, keep.order = TRUE, result = "variance.matrix")
```

Arguments

`target`	The `n` x `w` incidence `matrix` for the `w` effects targetted for prediction, or a `formula` from which the `matrix` can be generated.
`Gt`	The value of the variance component for the targetted effects or the `w` x `w` variance `matrix` of the `w` targetted effects. If the targetted effects are fixed, set `Gt` to 0.
`fixed`	The `n` x `f` incidence `matrix` for the `f` nuisance fixed effects and covariates, or a `formula` from which the `matrix` can be generated. The default is a `formula` for an intercept-only model.

random	A formula or a matrix. If a formula, it specifies the random effects from which the matrix for the contribution of the random effects to the variance matrix can be generated. If it is a matrix, it must be an n x n matrix and will be passed on to form the variance matrix of the observations. The default is 0, which implies that there are no random effects.
G	This term only needs to be set if random is a formula. Then it is set to a list, in which each component is either a single value or a matrix; there needs to be a component for each term in the expanded formula, with the order of the terms and components matching. If it is a single value, a diagonal matrix of dimension equal to the product of the numbers of levels of the factors in its term. If it is a matrix, its dimension must be equal to the product of the numbers of levels of the factors in its term.
R	The n x n residual variance matrix. If R is not set in the call, then it is set to the identity matrix.
design	A data.frame containing the design to be used in an experiment from which predictions are to be obtained. It is not required when the only formula specified is an intercept-only formula.
eliminate	The n x n projector onto the subspace corresponding to the effects to be eliminated from the information matrix prior to inverting it to form the variance matrix of the predicted effects. It is only appropriate to use this option when the effects to be predicted are fixed.
keep.order	A logical indicating whether the terms should keep their position in the expanded formula projector, or reordered so that main effects precede two-factor interactions, which precede three-factor interactions and so on.
result	A character indicating which matrix is to be returned: variance.matrix or information.matrix.

Details

The mixed model for which the predictions are to be obtained is of the form $\boldsymbol{Y} = \boldsymbol{X}\boldsymbol{\beta} + \boldsymbol{W}\boldsymbol{w} + \boldsymbol{Z}\boldsymbol{u} + \boldsymbol{e}$, where $\boldsymbol{W}$ is the incidence matrix for the target predicted effects $\boldsymbol{w}$, $\boldsymbol{X}$ is the is incidence matrix for the fixed nuisance effects $\boldsymbol{\beta}$, $\boldsymbol{Z}$ is the is incidence matrix for the random nuisance effects $\boldsymbol{u}$, $\boldsymbol{e}$ are the residuals; the $\boldsymbol{u}$ are assumed to have variance matrix $\boldsymbol{G}$ so that their contribution to the variance matrix for $\boldsymbol{Y}$ is $\boldsymbol{V}\boldsymbol{u} = \boldsymbol{Z}\boldsymbol{G}\boldsymbol{Z}^T$ and $\boldsymbol{e}$ is assumed to have variance matrix $\boldsymbol{R}$. If the target effects are random then the variance matrix for $\boldsymbol{w}$ is $\boldsymbol{G}_t$ so that their contribution to the variance matrix for $\boldsymbol{Y}$ is $\boldsymbol{W}\boldsymbol{G}_t\boldsymbol{W}^T$.

As described in Hooks et al. (2009, Equation 19), the information matrix is calculated as A <- t(W) %*% Vinv %*% W + ginv(Gg) - A%*%ginv(t(X)%*%Vinv%*%X)%*%t(A), where Vinv <- ginv(Vu + R), A = t(W) %*% Vinv %*% X and ginv(B) is the unique Moore-Penrose inverse of B formed using the eigendecomposition of B.

Then, if eliminate is set and the effects to be predicted are fixed then the reduced information matrix is calculated as A <- (I - eliminate) Vinv (I - eliminate).

Finally, if result is set to variance.matrix, the variance of the predicted effects is calculated: Vpred <- ginv(A) and returned; otherwise the information matrix A is returned. The rank of the matrix to be returned is obtain via a singular value decomposition of the information matrix, it being the number of nonzero eigenvalues. An eigenvalue is regarded as zero if it is less than daeTolerance, which is initially set to.Machine$double.eps ^ 0.5 (about 1.5E-08). The function set.daeTolerance can be used to change daeTolerance.

Value

A w x w matrix containing the variances and covariances of the predicted effects or the information matrix for the effects, depending on the setting of result. The matrix has its rank as an attribute.

Author(s)

Chris Brien

References

Hooks, T., Marx, D., Kachman, S., and Pedersen, J. (2009). Optimality criteria for models with random effects. *Revista Colombiana de Estadistica*, **32**, 17-31.

Smith, A. B., D. G. Butler, C. R. Cavanagh and B. R. Cullis (2015). Multi-phase variety trials using both composite and individual replicate samples: a model-based design approach. *Journal of Agricultural Science*, **153**, 1017-1029.

See Also

designAmeasures, mat.random, mat.Vpred.

Examples

```
## Reduced example from Smith et al. (2015)
## Generate two-phase design
mill.fac <- fac.gen(list(Mrep = 2, Mday = 2, Mord = 3))
field.lay <- fac.gen(list(Frep = 2, Fplot = 4))
field.lay$Variety <- factor(c("D","E","Y","W","G","D","E","M"),
                            levels = c("Y","W","G","M","D","E"))
start.design <- cbind(mill.fac, field.lay[c(3,4,5,8,1,7,3,4,5,8,6,2),])
rownames(start.design) <- NULL

## Set gammas
terms <- c("Variety", "Frep", "Frep:Fplot", "Mrep", "Mrep:Mday", "Mrep:Mday:Mord")
gammas <- c(1, 0.1, 0.2, 0.3, 0.2, 1)
names(gammas) <- terms

## Specify matrices to calculate the variance matrix of the predicted fixed Variety effects
W <- model.matrix(~ -1 + Variety, start.design)
Vu <- with(start.design, fac.vcmat(Mrep, gammas["Mrep"]) +
                         fac.vcmat(fac.combine(list(Mrep,Mday)), gammas["Mrep:Mday"]) +
                         fac.vcmat(Frep, gammas["Frep"]) +
                         fac.vcmat(fac.combine(list(Frep,Fplot)), gammas["Frep:Fplot"]))
R <- diag(1, nrow(start.design))

## Calculate variance matrix
Vp <- mat.Vpredicts(target = W, random=Vu, R=R, design = start.design)

## Calculate the variance matrix of the predicted random Variety effects using formulae
Vp <- mat.Vpredicts(target = ~ -1 + Variety, Gt = 1,
                    fixed = ~ 1,
                    random = ~ -1 + Mrep/Mday + Frep/Fplot,
                    G = as.list(gammas[c(4,5,2,3)]),
                    R = R, design = start.design)
designAmeasures(Vp)
```

```
## Calculate the variance matrix of the predicted fixed Variety effects,
## elminating the grand mean
n <- nrow(start.design)
Vp.reduc <- mat.Vpredicts(target = ~ -1 + Variety,
                          random = ~ -1 + Mrep/Mday + Frep/Fplot,
                          G = as.list(gammas[c(4,5,2,3)]),
                          eliminate = projector(matrix(1, nrow = n, ncol = n)/n),
                          design = start.design)
designAmeasures(Vp.reduc)
```

`McIntyreTMV.dat` *The design and data from McIntyre's (1955) two-phase experiment*

Description

McIntyre (1955) reports an investigation of the effect of four light intensities on the synthesis of tobacco mosaic virus in leaves of tobacco *Nicotiana tabacum* var. Hickory Pryor. It is a two-phase experiment: the first phase is a treatment phase, in which the four light treatments are randomized to the tobacco leaves, and the second phase is an assay phase, in which the tobacco leaves are randomized to the half-leaves of assay plants. For more details see the vignette accessed via `vignette("DesignNotes", package="dae")`.

Usage

```
data(McIntyreTMV.dat)
```

Format

A data.frame containing 196 observations of 4 variables.

Source

McIntyre, G. A. (1955) Design and Analysis of Two Phase Experiments. *Biometrics*, **11**, 324–334.

`meanop` *computes the projection matrix that produces means*

Description

Replaced by `fac.meanop`.

mpone *Converts the first two levels of a factor into the numeric values -1 and +1*

Description

Converts the first two `levels` of a `factor` into the numeric values -1 and +1.

Usage

```
mpone(factor)
```

Arguments

`factor`	The `factor` to be converted.

Value

A numeric `vector`.

Warning

If the `factor` has more than two `levels` they will be coerced to numeric values.

Author(s)

Chris Brien

See Also

`mpone` in package **dae**, `factor`, `relevel`.

Examples

```
## generate all combinations of two two-level factors
mp <- c("-", "+")
Frf3.trt <- fac.gen(list(A = mp, B = mp))

## add factor C, whose levels are the products of the levles of A and B
Frf3.trt$C <- factor(mpone(Frf3.trt$A)*mpone(Frf3.trt$B), labels = mp)
```

`no.reps` *Computes the number of replicates for an experiment*

Description

Computes the number of pure replicates required in an experiment to achieve a specified power.

Usage

```
no.reps(multiple=1., df.num=1.,
        df.denom=expression((df.num + 1.) * (r - 1.)), delta=1.,
        sigma=1., alpha=0.05, power=0.8, tol=0.1, print=FALSE)
```

Arguments

`multiple`	The multiplier, m, which when multiplied by the number of pure replicates of a treatment, r, gives the number of observations rm used in computing means for some, not necessarily proper, subset of the treatment factors; m is the replication arising from other treatment factors. However, for single treatment factor experiments the subset can only be the treatment factor and m = 1.
`df.num`	The degrees of freedom of the numerator of the F for testing the term involving the treatment factor subset.
`df.denom`	The degrees of freedom of the denominator of the F for testing the term involving the treatment factor subset.
`delta`	The true difference between a pair of means for some, not necessarily proper, subset of the treatment factors.
`sigma`	The population standard deviation.
`alpha`	The significance level to be used.
`power`	The minimum power to be achieved.
`tol`	The maximum difference tolerated between the power required and the power computed in determining the number of replicates.
`print`	`TRUE` or `FALSE` to have or not have a table of power calculation details printed out.

Value

A list containing `nreps`, a single `numeric` value containing the computed number of pure replicates, and `power`, a single `numeric` value containing the power for the computed number of pure replicates.

Author(s)

Chris Brien

See Also

`power.exp`, `detect.diff` in package **dae**.

Examples

```
## Compute the number of replicates (blocks) required for a randomized
## complete block design with four treatments.
no.reps(multiple = 1, df.num = 3,
        df.denom = expression(df.num * (r - 1)), delta = 5,
         sigma = sqrt(20), print = TRUE)
```

`Oats.dat` *Data for an experiment to investigate nitrogen response of 3 oats varieties*

Description

Yates (1937) describes a split-plot experiment that investigates the effects of three varieties of oats and four levels of Nitrogen fertilizer. The varieties are assigned to the main plots using a randomized complete block design with 6 blocks and the nitrogen levels are randomly assigned to the subplots in each main plot.

The columns in the data frame are: Blocks, Wplots, Subplots, Variety, Nitrogen, xNitrogen, Yield. The column xNitrogen is a numeric version of the factor Nitrogen. The response variable is Yield.

Usage

```
data(Oats.dat)
```

Format

A data.frame containing 72 observations of 7 variables.

Author(s)

Chris Brien

Source

Yates, F. (1937). The Design and Analysis of Factorial Experiments. *Imperial Bureau of Soil Science, Technical Communication*, **35**, 1-95.

`p2canon.object` *Description of a p2canon object*

Description

An object of class `p2canon` that contains information derived from two `formulae` using `projs.2canon`.

Value

A list of class p2canon. It has two components: decomp and aliasing. The decomp component iscomposed as follows:

- It has a component for each component of Q1.
- Each of the components for Q1 is a list; each of these lists has one component for each of Q2 and a component Pres.
- Each of the Q2 components is a list of three components: pairwise, adjusted and Qproj. These components are based on an eigenalysis of the relationship between the projectors for the parent Q1 and Q2 components.
  1. Each pairwise component is based on the nonzero canonical efficiency factors for the joint decomposition of the two parent projectors (see proj2.eigen).
  2. An adjusted component is based on the nonzero canonical efficiency factors for the joint decomposition of the Q1 component and the Q2 component, the latter adjusted for all Q2 projectors that have occured previously in the list.
  3. The Qproj component is the adjusted projector for the parent Q2 component.
- The pairwise and adjusted components have the following components: efficiencies, aefficiency, mefficiency, sefficiency, eefficiency, xefficiency, order and dforthog – for details see efficiency.criteria.

The aliasing component is a data.frame decribing the aliasing between terms corresponding to two Q2 projectors when estimated in subspaces corresponding to a Q1 projector.

Author(s)

Chris Brien

See Also

projs.2canon, designAnatomy, pcanon.object.

---

pcanon.object *Description of a pcanon object*

Description

An object of class pcanon that contains information derived from several formulae using designAnatomy.

Value

A list of class pcanon that has four components: (i) Q, (ii) terms, (iii) sources, (iv) marginality, and (v) aliasing. Each component is a list with as many components as there are formulae in the formulae list supplied to designAnatomy.

The Q list is made up of the following components:

1. The first component is the joint decomposition of two structures derived from the first two formulae, being the p2canon.object produced by projs.2canon.
2. Then there is a component for each further formulae; it contains the p2canon.object obtained by applying projs.2canon to the structure for a formula and the already established joint decomposition of the structures for the previous formulae in the formulae.

3. The last component contains the the list of the projectors that give the combined canonical decomposition derived from all of the formulae.

The terms, sources, marginalty and aliasing lists have a component for each formula in the formulae argument to designAnatomy, Each component of the terms and sources lists has a character vector containing the terms or sources derived from its formula. For the marginality component, each component is the marginality matrix for the terms derived from its formula. For the aliasing component, each component is the aliasing data.frame for the source derived from its formula. The components of these four lists are produced by pstructure.formula and are copied from the pstructure.object for the formula. The names of the components of these four lists will be the names of the components in the formulae list.

The object has the attribute labels, which is set to "terms" or "sources" according to which of these were used to label the projectors when the object was created.

Author(s)

Chris Brien

See Also

designAnatomy, p2canon.object.

---

porthogonalize.list *Takes a list of* projectors *and constructs a* pstructure.object *that includes projectors, each of which has been orthogonalized to all projectors preceding it in the list.*

Description

Constructs a pstructure.object that includes a set of mutually orthogonal projectors, one for each of the projectors in the list. These specify a structure, or an orthogonal decomposition of the data space. This function externalizes the process previously performed within pstructure.formula to orthogonalize projectors. There are three methods available for carrying out orthogonalization: differencing, eigenmethods or the default hybrid method.

It is possible to use this function to find out what sources are associated with the terms in a model and to determine the marginality between terms in the model. The marginality matrix can be saved.

Usage

```
## S3 method for class 'list'
porthogonalize(projectors, formula = NULL, keep.order = TRUE,
               grandMean = FALSE, orthogonalize = "hybrid", labels = "sources",
               marginality = NULL, check.marginality = TRUE,
               omit.projectors = FALSE,
               which.criteria = c("aefficiency","eefficiency","order"),
               aliasing.print = TRUE, ...)
```

Arguments

projectors	A list each of whose components is a projector.
formula	An object of class formula from which the projectors have been obtained. If NULL, then the differencing option of orthogonalize is not available.
keep.order	A logical indicating whether the terms should keep their position in the expanded formula projector, or reordered so that main effects precede two-factor interactions, which precede three-factor interactions and so on.
grandMean	A logical indicating whether the projector for the grand mean is to be included in the set produced.
orthogonalize	A character vector indicating the method for orthogonalizing a projector to those for terms that occurred previously in the formula. Three options are available: hybrid; differencing; eigenmethods, unless formula is NULL in which case differencing is not available. The hybrid option is the most general and uses the relationships between the projection operators for the terms in the formula to decide which projectors to substract and which to orthogonalize using eigenmethods. The differencing option subtracts, from the current projector, those previously orthogonalized projectors for terms whose factors are a subset of the current projector's factors. The eigenmethods option recursively orthogonalizes the projectors using an eigenanalysis of each projector with previously orthogonalized projectors.
labels	A character nominating the type of labels to be used in labelling the projectors, and which will be used also in the output tables, such the tables of the aliasing in the structure. The two alternatives are terms and sources. Terms have all factors/variables in it separated by colons (:). Sources have factors/variables in them that represent interactions separated by hashes (#); if some factors are nested within others, the nesting factors are surrounded by square brackets ([and]) and separated by colons (:). If some generalized, or combined, factors have no marginal terms, the constituent factors are separated by colons (:) and if they interact with other factors in the source they will be parenthesized.
marginality	A square matrix that can be used to supply the marginality matrix when it is desired to overwrite the calculated marginality matrix or when it is not being calculated. It should consist of zeroes and ones that gives the marginalites of the terms in the formula. It must have the row and column names set to the terms from the expanded formula, including being in the same order as these terms. The entry in the ith row and jth column will be one if the ith term is marginal to the jth term i.e. the column space of the ith term is a subspace of that for the jth term and so the source for the jth term is to be made orthogonal to that for the ith term. Otherwise, the entries are zero. A row and column should not be included for the grand mean even if grandMean is TRUE.
check.marginality	A logical indicating whether the marginality matrix, when it is supplied, is to be checked against that computed by porthogonalize.list. It is ignored when orthogonalize is set to eigenmethods.
omit.projectors	A logical, which, if TRUE, results in the projectors in the Q of the pstructure.object being replaced by their degrees of freedom. These will be the degrees of freedom of the sources. This option is included a device for saving storage when the projectors are not required for further analysis.
which.criteria	A character vector nominating the efficiency criteria to be included in the summary of aliasing between terms. It can be none, all or some combination

	of aefficiency, mefficiency, sefficiency, eefficiency, xefficiency, order and dforthog – for details see efficiency.criteria. If none, no summary is printed.
aliasing.print	A logical indicating whether the aliasing between sources within the structure is to be printed.
...	further arguments passed to terms.

Details

It is envisaged that the projectors in the list supplied to the projectors argument correspond to the terms in a linear model. One way to generate them is to obtain the design matrix $\mathbf{X}$ for a term and then calculate its projector as $\mathbf{X}(\mathbf{X}'\mathbf{X})^{-}\mathbf{X}'$, There are three methods available for orhtogonalizing the supplied projectors: differencing, eigenmethods or the default hybrid method.

Differencing relies on comparing the factors involved in two terms, one previous to the other, to identify whether to subtract the orthogonalized projector for the previous term from the primary projector of the other. It does so if factors/variables for the previous term are a subset of the factors/variablesfor for the other term. This relies on ensuring that all projectors whose factors/variables are a subset of the current projector occur before it in the expanded formula. It is checked that the set of matrices are mutually orthogonal. If they are not then a warning is given. It may happen that differencing does not produce a projector, in which case eigenmethods must be used.

Eigenmethods forces each projector to be orthogonal to all terms previous to it in the expanded formula. It uses equation 4.10 of James and Wilkinson (1971), which involves calculating the canonical efficiency factors for pairs of primary projectors. It produces a table of efficiency criteria for partially aliased terms. Again, the order of terms is crucial. This method has the disadvantage that the marginality of terms is not determined and so sources names are set to be the same as the term names, unless a marginality matrix is supplied.

The hybrid method is the most general and uses the relationships between the projection operators for the terms in the formula to decide which projectors to subtract and which to orthogonalize using eigenmethods. If $\mathbf{Q}_i$ and $\mathbf{Q}_j$ are two projectors for two different terms, with $i < j$, then

1. if $\mathbf{Q}_j\mathbf{Q}_i \neq \mathbf{0}$ then have to orthogonalize $\mathbf{Q}_j$ to $\mathbf{Q}_i$.
2. if $\mathbf{Q}_j\mathbf{Q}_i = \mathbf{Q}_j$ then, if $\mathbf{Q}_i = \mathbf{Q}_j$, they are equal and $\mathbf{Q}_j$ will be removed from the list of terms; otherwise they are marginal and $\mathbf{Q}_i$ is subtracted from $\mathbf{Q}_j$.
3. if have to orthogonalize and $\mathbf{Q}_j\mathbf{Q}_i = \mathbf{Q}_i$ then $\mathbf{Q}_j$ is aliased with previous terms and will be removed from the list of terms; otherwise $\mathbf{Q}_i$ is partially aliased with $\mathbf{Q}_j$ and $\mathbf{Q}_j$ is orthogonalized to $\mathbf{Q}_i$ using eigenmethods.

The order of projections matrices in the list is crucial in this process.

Of the three methods, eigenmethods is least likely to fail, but it does not establish the marginality between the terms. It is often needed when there is nonorthogonality between terms, such as when there are several linear covariates. It can also be more efficeint in these circumstances.

The process can be computationally expensive, particularly for a large data set (500 or more observations) and/or when many terms are to be orthogonalized.

If the error Matrix is not idempotent should occur then, especially if there are many terms, one might try using set.daeTolerance to reduce the tolerance used in determining if values are either the same or are zero; it may be necessary to lower the tolerance to as low as 0.001. Also, setting orthogonalize to eigenmethods is worth a try.

Value

A pstructure.object.

Author(s)

Chris Brien

References

James, A. T. and Wilkinson, G. N. (1971) Factorization of the residual operator and canonical decomposition of nonorthogonal factors in the analysis of variance. *Biometrika*, **58**, 279-294.

See Also

pstructure.formula, proj2.efficiency, proj2.combine, proj2.eigen, projs.2canon in package **dae**, eigen.

projector for further information about this class.

Examples

```
## PBIBD(2) from p. 379 of Cochran and Cox (1957) Experimental Designs.
## 2nd edn Wiley, New York
PBIBD2.unit <- list(Block = 6, Unit = 4)
PBIBD2.nest <- list(Unit = "Block")
trt <- factor(c(1,4,2,5, 2,5,3,6, 3,6,1,4, 4,1,5,2, 5,2,6,3, 6,3,4,1))
PBIBD2.lay <- designRandomize(allocated = trt,
                              recipient = PBIBD2.unit,
                              nested.recipients = PBIBD2.nest)
## manually obtain projectors for units
Q.G <- projector(matrix(1, nrow=24, ncol=24)/24)
Q.B <- projector(fac.meanop(PBIBD2.lay$Block))
Q.BU <- projector(diag(1, nrow=24))

## manually obtain projector for trt
Q.T <- projector(fac.meanop(PBIBD2.lay$trt) - Q.G)

##Orthogonalize the projectors using porthogonalize.list
Qs <- list(Mean = Q.G, Block = Q.B, "Block:Unit" = Q.BU)
struct <- porthogonalize(Qs, grandMean = TRUE)
Qs <- struct$Q
(lapply(Qs, degfree))

#Add a linear covariate
PBIBD2.lay <- within(PBIBD2.lay,
                     {
                       cBlock <- as.numfac(Block)
                       cBlock <- cBlock - mean(unique(cBlock))
                     })
X <- model.matrix(~ cBlock, data = PBIBD2.lay)
Q.cB <- projector(X %*% mat.ginv(t(X) %*% X) %*% t(X))
Qs <- list(cBlock = Q.cB, Block = Q.B, "Block:Unit" = Q.BU)
struct <- porthogonalize(Qs, grandMean = FALSE)
Qs <- struct$Q
(lapply(Qs, degfree))
```

power.exp *Computes the power for an experiment*

Description

Computes the power for an experiment.

Usage

```
power.exp(rm=5., df.num=1., df.denom=10., delta=1., sigma=1.,
          alpha=0.05, print=FALSE)
```

Arguments

rm	The number of observations used in computing a mean.
df.num	The degrees of freedom of the numerator of the F for testing the term involving the means.
df.denom	The degrees of freedom of the denominator of the F for testing the term involving the means.
delta	The true difference between a pair of means.
sigma	The population standard deviation.
alpha	The significance level to be used.
print	TRUE or FALSE to have or not have a table of power calculation details printed out.

Value

A single numeric value containing the computed power.

Author(s)

Chris Brien

See Also

no.reps, detect.diff in package **dae**.

Examples

```
## Compute power for a randomized complete block design with four treatments
## and five blocks.
rm <- 5
power.exp(rm = rm, df.num = 3, df.denom = 3 * (rm - 1), delta = 5,
          sigma = sqrt(20),print = TRUE)
```

print.aliasing *Print an aliasing data.frame*

Description

Prints an aliasing data.frame.

Usage

```
## S3 method for class 'aliasing'
print(x, which.criteria = c("aefficiency","eefficiency","order"),  ...)
```

Arguments

x	The data.frame that is also of class aliasing and is to be printed.
which.criteria	A character vector nominating the efficiency criteria to be included in the summary of aliasing between terms. It can be none, all or some combination of aefficiency, mefficiency, sefficiency, eefficiency, xefficiency, order and dforthog – for details see efficiency.criteria. If none, no criteria are printed.
...	Further arguments passed to the print method for data.frame.

Author(s)

Chris Brien

See Also

print, print.default, show.

Examples

```
## Generate a data.frame with 3 factors length 12
pseudo.lay <- data.frame(pl = factor(1:12),
                         ab = factor(rep(1:4, times=3)),
                         a = factor(rep(1:2, times=6)))


## create a pstructure object
trt.struct <- pstructure(~ ab+a, data = pseudo.lay)

## print the object either using the Method function, the generic function or show
print.aliasing(trt.struct$aliasing)
print(trt.struct$aliasing, which.criteria = "none")
trt.struct$aliasing
```

print.projector *Print projectors*

Description

Print an object of class "projector", displaying the matrix and its degrees of freedom (rank).

Usage

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

Arguments

x	The object of class "projector" to be printed.
...	Further arguments passed to or from other methods.

Author(s)

Chris Brien

See Also

print, print.default, show.

projector for further information about this class.

Examples

```
## set up a 2 x 2 mean operator that takes the mean of a vector of 2 values
m <- matrix(rep(0.5,4), nrow=2)

## create an object of class projector
proj.m <- projector(m)

## print the object either using the Method function, the generic function or show
print.projector(proj.m)
print(proj.m)
proj.m
```

print.pstructure *Prints a pstructure.object*

Description

Prints a pstructure.object, which is of class pstructure. The df, terms and sources are coerced into a data.frame and printed; the marginality matrix is printed separately.

Usage

```
## S3 method for class 'pstructure'
print(x, which = "all", ...)
```

Arguments

x	The pstructure.object, which is of class pstructure and is to be printed.
which	A character vector nominating the components of the pstructure.object to print. Must be all or some combination of projectors, marginality, and aliasing.
...	Further arguments passed to print.aliasing.

Author(s)

Chris Brien

See Also

print, print.default, show.

Examples

```
## Generate a data.frame with 4 factors, each with three levels, in standard order
ABCD.lay <- fac.gen(list(A = 3, B = 3, C = 3, D = 3))

## create a pstructure object based on the formula ((A*B)/C)*D
ABCD.struct <- pstructure.formula(~ ((A*B)/C)*D, data =ABCD.lay)

## print the object either using the Method function, the generic function or show
print.pstructure(ABCD.struct)
print(ABCD.struct)
ABCD.struct
```

---

print.summary.p2canon *Prints the values in an summary.p2canon object*

Description

Prints a summary.p2canon object, which is also a data.frame, in a pretty format.

Usage

```
## S3 method for class 'summary.p2canon'
print(x, ...)
```

Arguments

x	A summary.p2canon object.
...	further arguments passed to print.

Value

No value is returned.

Author(s)

Chris Brien

See Also

summary.p2canon

Examples

```
## PBIBD(2) from p. 379 of Cochran and Cox (1957) Experimental Designs.
## 2nd edn Wiley, New York
PBIBD2.unit <- list(Block = 6, Unit = 4)
PBIBD2.nest <- list(Unit = "Block")
trt <- factor(c(1,4,2,5, 2,5,3,6, 3,6,1,4, 4,1,5,2, 5,2,6,3, 6,3,4,1))
PBIBD2.lay <- designRandomize(allocated = trt,
                              recipient = PBIBD2.unit,
                              nested.recipients = PBIBD2.nest)

##obtain projectors using pstructure
unit.struct <- pstructure(~ Block/Unit, data = PBIBD2.lay)
trt.struct <- pstructure(~ trt, data = PBIBD2.lay)

##obtain combined decomposition and print summary
unit.trt.p2canon <- projs.2canon(unit.struct$Q, trt.struct$Q)
summ <- summary(unit.trt.p2canon)
print(summ)
```

---

print.summary.pcanon *Prints the values in an* summary.pcanon *object*

Description

Prints a summary.pcanon object, which is also a data.frame, in a pretty format.

Usage

```
## S3 method for class 'summary.pcanon'
print(x, aliasing.print = TRUE, ...)
```

Arguments

x	A summary.pcanon object.
aliasing.print	A logical indicating whether the aliasing between sources is to be printed. Ignored for legacy summary.pcanon objects resulting from versions prior to 3.0-0 and so using projs.canon
...	further arguments passed to print.

Value

No value is returned.

Author(s)

Chris Brien

See Also

summary.pcanon

Examples

```
## PBIBD(2) from p. 379 of Cochran and Cox (1957) Experimental Designs.
## 2nd edn Wiley, New York
PBIBD2.unit <- list(Block = 6, Unit = 4)
PBIBD2.nest <- list(Unit = "Block")
trt <- factor(c(1,4,2,5, 2,5,3,6, 3,6,1,4, 4,1,5,2, 5,2,6,3, 6,3,4,1))
PBIBD2.lay <- designRandomize(allocated = trt,
                              recipient = PBIBD2.unit,
                              nested.recipients = PBIBD2.nest)

##obtain combined decomposition and summarize
unit.trt.canon <- designAnatomy(list(unit=~ Block/Unit, trt=~ trt),
                                data = PBIBD2.lay)
summ <- summary(unit.trt.canon, which = c("aeff","eeff","order"))
print(summ)
```

---

proj2.combine — *Compute the projection and Residual operators for two, possibly nonorthogonal, projectors*

Description

The canonical relationship between a pair of projectors is established by decomposing the range of Q1 into a part that pertains to Q2 and a part that is orthogonal to Q2. It also produces the nonzero canonical efficiency factors for the joint decomposition of Q1 and Q and the corresponding eigenvectors of Q1 (James and Wilkinson, 1971). Q1 and Q2 may be nonorthogonal.

Usage

```
proj2.combine(Q1, Q2)
```

Arguments

Q1	A symmetric projector whose range is to be decomposed.
Q2	A symmetric projector whose range in Q1 is required.

Details

The nonzero canonical efficiency factors are the nonzero eigenvalues of Q1 %*% Q2 %*% Q1 (James and Wilkinson, 1971). An eigenvalue is regarded as zero if it is less than daeTolerance, which is initially set to .Machine$double.eps ^ 0.5 (about 1.5E-08). The function set.daeTolerance can be used to change daeTolerance.

The eigenvectors are the eigenvectors of Q1 corresponding to the nonzero canonical efficiency factors. The eigenvectors for Q2 can be obtained by premultiplying those for Q1 by Q2.

Qres is computed using equation 4.10 from James and Wilkinson (1971), if the number of distinct canonical efficiency factors is less than 10. If this fails to produce a projector or the number of distinct canonical efficiency factors is 10 or more, equation 5.3 of Payne and Tobias (1992) is used to obtain Qres. In this latter case, Qres = Q1 - Q1 %*% ginv(Q2 %*% Q1 %*% Q2) %*% Q1. Qconf is obtained by subtracting Qres from Q1.

Value

A `list` with the following components:

1. **efficiencies:** a `vector` containing the nonzero canonical efficiency factors;
2. **eigenvectors:** an n x r `matrix`, where n is the order of the projectors and r is the number of nonzero canonical efficiency factors; it contains the eigenvectors of Q1 corresponding to the nonzero canonical efficiency factors.
3. **Qconf:** a `projector` onto the part of the range of Q1 with which Q2 is confounded;
4. **Qres:** a `projector` onto the part of the range of Q1 that is orthogonal to the range of Q2.

Author(s)

Chris Brien

References

James, A. T. and Wilkinson, G. N. (1971) Factorization of the residual operator and canonical decomposition of nonorthogonal factors in the analysis of variance. *Biometrika*, **58**, 279–294.

Payne, R. W. and R. D. Tobias (1992). General balance, combination of information and the analysis of covariance. *Scandinavian Journal of Statistics*, **19**, 3–23.

See Also

`proj2.eigen`, `proj2.efficiency`, `decomp.relate` in package **dae**.

`projector` for further information about this class.

Examples

```
## PBIBD(2) from p. 379 of Cochran and Cox (1957) Experimental Designs.
## 2nd edn Wiley, New York
PBIBD2.unit <- list(Block = 6, Unit = 4)
PBIBD2.nest <- list(Unit = "Block")
trt <- factor(c(1,4,2,5, 2,5,3,6, 3,6,1,4, 4,1,5,2, 5,2,6,3, 6,3,4,1))
PBIBD2.lay <- designRandomize(allocated = trt,
                              recipient = PBIBD2.unit,
                              nested.recipients = PBIBD2.nest)

## obtain sets of projectors
unit.struct <- pstructure(~ Block/Unit, data = PBIBD2.lay)
trt.struct <- pstructure(~ trt, data = PBIBD2.lay)

## obtain the projection operators for the interblock analysis
PBIBD2.Bops <- proj2.combine(unit.struct$Q[["Unit[Block]"]], trt.struct$Q[["trt"]])
Q.B.T <- PBIBD2.Bops$Qconf
Q.B.res <- PBIBD2.Bops$Qres

## demonstrate their orthogonality
is.allzero(Q.B.T %*% Q.B.res)
```

proj2.efficiency *Computes the canonical efficiency factors for the joint decomposition of two projectors*

Description

Computes the canonical efficiency factors for the joint decomposition of two projectors (James and Wilkinson, 1971).

Usage

```
proj2.efficiency(Q1, Q2)
```

Arguments

Q1	An object of class "projector".
Q2	An object of class "projector".

Details

The nonzero canonical efficiency factors are the nonzero eigenvalues of Q1 %*% Q2 %*% Q1 (James and Wilkinson, 1971). An eigenvalue is regarded as zero if it is less than daeTolerance, which is initially set to .Machine$double.eps ^ 0.5 (about 1.5E-08). The function set.daeTolerance can be used to change daeTolerance.

Value

A vector containing the nonzero canonical efficiency factors.

Author(s)

Chris Brien

References

James, A. T. and Wilkinson, G. N. (1971) Factorization of the residual operator and canonical decomposition of nonorthogonal factors in the analysis of variance. *Biometrika*, **58**, 279-294.

See Also

efficiency.criteria, proj2.eigen, proj2.combine in package **dae**, eigen.

projector for further information about this class.

Examples

```
## PBIBD(2) from p. 379 of Cochran and Cox (1957) Experimental Designs.
## 2nd edn Wiley, New York
PBIBD2.unit <- list(Block = 6, Unit = 4)
PBIBD2.nest <- list(Unit = "Block")
trt <- factor(c(1,4,2,5, 2,5,3,6, 3,6,1,4, 4,1,5,2, 5,2,6,3, 6,3,4,1))
PBIBD2.lay <- designRandomize(allocated = trt,
                              recipient = PBIBD2.unit,
```

```
                              nested.recipients = PBIBD2.nest)

## obtain sets of projectors
unit.struct <- pstructure(~ Block/Unit, data = PBIBD2.lay)
trt.struct <- pstructure(~ trt, data = PBIBD2.lay)

## save intrablock efficiencies
eff.intra <- proj2.efficiency(unit.struct$Q[["Block"]], trt.struct$Q[["trt"]])
```

`proj2.eigen` *Canonical efficiency factors and eigenvectors in joint decomposition of two projectors*

Description

Computes the canonical efficiency factors for the joint decomposition of two projectors and the eigenvectors corresponding to the first projector (James and Wilkinson, 1971).

Usage

```
proj2.eigen(Q1, Q2)
```

Arguments

Q1	An object of class "projector".
Q2	An object of class "projector".

Details

The component efficiencies is a `vector` containing the nonzero canonical efficiency factors for the joint decomposition of the two projectors. The nonzero canonical efficiency factors are the nonzero eigenvalues of Q1 %*% Q2 %*% Q1 (James and Wilkinson, 1971). An eigenvalue is regarded as zero if it is less than `daeTolerance`, which is initially set to `.Machine$double.eps ^ 0.5` (about 1.5E-08). The function `set.daeTolerance` can be used to change `daeTolerance`.

The component eigenvectors is an n x r `matrix`, where n is the order of the projectors and r is the number of nonzero canonical efficiency factors; it contains the eigenvectors of Q1 corresponding to the nonzero canonical efficiency factors. The eigenvectors for Q2 can be obtained by premultiplying those for Q1 by Q2.

Value

A `list` with components efficiencies and eigenvectors.

Author(s)

Chris Brien

References

James, A. T. and Wilkinson, G. N. (1971) Factorization of the residual operator and canonical decomposition of nonorthogonal factors in the analysis of variance. *Biometrika*, **58**, 279-294.

See Also

proj2.efficiency, proj2.combine in package **dae**, eigen.

projector for further information about this class.

Examples

```
## PBIBD(2) from p. 379 of Cochran and Cox (1957) Experimental Designs.
## 2nd edn Wiley, New York
PBIBD2.unit <- list(Block = 6, Unit = 4)
PBIBD2.nest <- list(Unit = "Block")
trt <- factor(c(1,4,2,5, 2,5,3,6, 3,6,1,4, 4,1,5,2, 5,2,6,3, 6,3,4,1))
PBIBD2.lay <- designRandomize(allocated = trt,
                              recipient = PBIBD2.unit,
                              nested.recipients = PBIBD2.nest)

## obtain sets of projectors
unit.struct <- pstructure(~ Block/Unit, data = PBIBD2.lay)
trt.struct <- pstructure(~ trt, data = PBIBD2.lay)

## obtain intra- and inter-block decompositions
decomp.inter <- proj2.eigen(unit.struct$Q[["Block"]], trt.struct$Q[["trt"]])
decomp.intra <- proj2.eigen(unit.struct$Q[["Unit[Block]"]], trt.struct$Q[["trt"]])

#extract intrablock efficiencies
decomp.intra$efficiencies
```

`projector` *Create projectors*

Description

The class "projector" is the subclass of the class "matrix" in which matrices are square, symmetric and idempotent.

The function `projector` tests whether a matrix satisfies these criteria and if it does creates a "projector" object, computing the projector's degrees of freedom and adding them to the object.

Usage

```
projector(Q)
```

Arguments

`Q`	The matrix to be made into a projector.

Details

In checking that the matrix is square, symmetric and idempotent, the equality of the matrix with either its transpose or square is tested. In this, a difference in elements is considered to be zero if it is less than `daeTolerance`, which is initially set to `.Machine$double.eps ^ 0.5` (about 1.5E-08). The function set.daeTolerance can be used to change `daeTolerance`.

Value

An object of Class "projector" that consists of a square, summetric, idempotent matrix and degrees of freedom (rank) of the matrix.

Author(s)

Chris Brien

See Also

degfree, correct.degfree in package **dae**.

projector for further information about this class.

Examples

```
## set up a 2 x 2 mean operator that takes the mean of a vector of 2 values
m <- matrix(rep(0.5,4), nrow=2)

## create an object of class projector
proj.m <- projector(m)

## check that it is a valid projector
is.projector(proj.m)
```

---

projector-class *Class projector*

Description

The class "projector" is the subclass of matrices that are square, symmetric and idempotent.

is.projector is the membership function for this class.

degfree is the extractor function for the degrees of freedom and degfree<- is the replacement function.

correct.degfree checks whether the stored degrees of freedom are correct.

Objects from the Class

An object of class "projector" consists of a square, symmetric, idempotent matrix along with its degrees of freedom (rank).

Objects can be created by calls of the form new("projector", data, nrow, ncol, byrow, dimnames, ...). However, this does not add the degrees of freedom to the object. These can be added using the replacement function degfree<-. Alternatively, the function projector creates the new object from a matrix, adding its degrees of freedom at the same time.

Slots

.Data: Object of class "matrix"

degfree: Object of class "integer"

Extends

Class "matrix", from data part. Class "array", by class "matrix", distance 2. Class "structure", by class "matrix", distance 3. Class "vector", by class "matrix", distance 4, with explicit coerce.

Methods

coerce `signature(from = "projector", to = "matrix")`

print `signature(x = "projector")`

show `signature(object = "projector")`

Author(s)

Chris Brien

See Also

`projector`, `degfree`, `correct.degfree` in package **dae**.

Examples

```
showClass("projector")

## set up a 2 x 2 mean operator that takes the mean of a vector of 2 values
m <- matrix(rep(0.5,4), nrow=2)

## create an object of class projector
proj.m <- projector(m)

## check that it is a valid projector
is.projector(proj.m)

## create a projector based on the matrix m
proj.m <- new("projector", data=m)

## add its degrees of freedom and print the projector
degfree(proj.m) <- proj.m
```

---

projs.2canon *A canonical analysis of the relationships between two sets of projectors*

Description

Computes the canonical efficiency factors for the joint decomposition of two structures or sets of mutually orthogonally projectors (Brien and Bailey, 2009), orthogonalizing projectors in the Q2 `list` to those earlier in the `list` of projectors with which they are partially aliased. The results can be summarized in the form of a skeleton ANOVA table.

Usage

```
projs.2canon(Q1, Q2)
```

Arguments

Q1	A list whose components are objects of class "projector".
Q2	A list whose components are objectsof class "projector".

Details

Two loops, one nested within the other, are performed. The first cycles over the components of Q1 and the nested loop cycles over the components of Q2. The joint decomposition of the two projectors in each cycle, one from Q1 (say Q1[[i]]) and the other from Q2 (say Q2[[j]]) is obtained using proj2.combine. In particular, the nonzero canonical efficiency factors for the joint decomposition of the two projectors is obtained. The nonzero canonical efficiency factors are the nonzero eigenvalues of Q1[[i]] %*% Q2[[j]] %*% Q1[[i]] (James and Wilkinson, 1971). An eigenvalue is regarded as zero if it is less than daeTolerance, which is initially set to .Machine$double.eps ^ 0.5 (about 1.5E-08). The function set.daeTolerance can be used to change daeTolerance.

However, a warning occurs if any pair of Q2 projectors (say Q2[[j]] and Q2[[k]]) do not have adjusted orthgonality with respect to any Q1 projector (say Q1[[i]]), because they are partially aliased. That is, if Q2[[j]] %*% Q1[[i]] %*% Q2[[k]] is nonzero for any pair of different Q2 projectors and any Q1 projector. When it is nonzero, the projector for the later term in the list of projectors is orthogonalized to the projector that is earlier in the list. A list of such projectors is returned in the aliasing component of the p2canon.object. The entries in the aliasing component gives the amount of information that is aliased with previous terms.

Value

A p2canon.object.

Author(s)

Chris Brien

References

Brien, C. J. and R. A. Bailey (2009). Decomposition tables for multitiered experiments. I. A chain of randomizations. *The Annals of Statistics*, **36**, 4184 - 4213.

James, A. T. and Wilkinson, G. N. (1971) Factorization of the residual operator and canonical decomposition of nonorthogonal factors in the analysis of variance. *Biometrika*, **58**, 279-294.

See Also

summary.p2canon, efficiencies.p2canon, projs.combine.p2canon, pstructure , proj2.efficiency, proj2.combine, proj2.eigen, efficiency.criteria in package **dae**, eigen.

projector for further information about this class.

Examples

```
## PBIBD(2) from p. 379 of Cochran and Cox (1957) Experimental Designs.
## 2nd edn Wiley, New York
PBIBD2.unit <- list(Block = 6, Unit = 4)
PBIBD2.nest <- list(Unit = "Block")
trt <- factor(c(1,4,2,5, 2,5,3,6, 3,6,1,4, 4,1,5,2, 5,2,6,3, 6,3,4,1))
PBIBD2.lay <- designRandomize(allocated = trt,
                              recipient = PBIBD2.unit,
                              nested.recipients = PBIBD2.nest)
```

```
##obtain projectors using pstructure
unit.struct <- pstructure(~ Block/Unit, data = PBIBD2.lay)
trt.struct <- pstructure(~ trt, data = PBIBD2.lay)

##obtain combined decomposition and summarize
unit.trt.p2canon <- projs.2canon(unit.struct$Q, trt.struct$Q)
summary(unit.trt.p2canon)
```

`projs.combine.p2canon` *Extract, from a p2canon object, the projectors that give the combined canonical decomposition*

Description

Extracts, from a p2canon object obtained using `projs.2canon`, the projectors that give the combined canonical decomposition of two sets of projectors (Brien and Bailey, 2009).

Usage

```
projs.combine.p2canon(object)
```

Arguments

`object`	A `list` of class p2canon produced by `projs.2canon`.

Value

A `list`, each of whose components is a projector in the decomposition.

Author(s)

Chris Brien

References

Brien, C. J. and R. A. Bailey (2009). Decomposition tables for multitiered experiments. I. A chain of randomizations. *The Annals of Statistics*, **36**, 4184 - 4213.

See Also

`projs.2canon`, `proj2.eigen`, `proj2.combine` in package **dae**.

`projector` for further information about this class.

Examples

```
## PBIBD(2) from p. 379 of Cochran and Cox (1957) Experimental Designs.
## 2nd edn Wiley, New York
PBIBD2.unit <- list(Block = 6, Unit = 4)
PBIBD2.nest <- list(Unit = "Block")
trt <- factor(c(1,4,2,5, 2,5,3,6, 3,6,1,4, 4,1,5,2, 5,2,6,3, 6,3,4,1))
PBIBD2.lay <- designRandomize(allocated = trt,
                              recipient = PBIBD2.unit,
```

```
                              nested.recipients = PBIBD2.nest)

## obtain sets of projectors
unit.struct <- pstructure(~ Block/Unit, data = PBIBD2.lay)
trt.struct <- pstructure(~ trt, data = PBIBD2.lay)

##obtain combined decomposition
unit.trt.p2canon <- projs.2canon(unit.struct$Q, trt.struct$Q)
UcombineT <- projs.combine.p2canon(unit.trt.p2canon)
```

`pstructure.formula` *Takes a formula and constructs a* `pstructure.object` *that includes the orthogonalized projectors for the terms in a formula*

Description

Constructs a `pstructure.object` that includes a set of mutually orthogonal projectors, one for each term in the formula. These are used to specify a structure, or an orthogonal decomposition of the data space. There are three methods available for orthogonalizing the projectors corresponding to the terms in the `formula`: `differencing`, `eigenmethods` or the default `hybrid` method.

It is possible to use this function to find out what sources are associated with the terms in a model and to determine the marginality between terms in the model. The marginality matrix can be saved.

Usage

```
## S3 method for class 'formula'
pstructure(formula, keep.order = TRUE, grandMean = FALSE,
           orthogonalize = "hybrid", labels = "sources",
           marginality = NULL, check.marginality = TRUE,
           omit.projectors = FALSE,
           which.criteria = c("aefficiency","eefficiency","order"),
           aliasing.print = TRUE, data = NULL, ...)
```

Arguments

`formula`	An object of class `formula` from which the terms will be obtained.
`keep.order`	A `logical` indicating whether the terms should keep their position in the expanded `formula` projector, or reordered so that main effects precede two-factor interactions, which precede three-factor interactions and so on.
`grandMean`	A `logical` indicating whether the projector for the grand mean is to be included in the set produced.
`orthogonalize`	A `character` vector indicating the method for orthogonalizing a projector to those for terms that occurred previously in the formula. Three options are available: `hybrid`; `differencing`; `eigenmethods`. The `hybrid` option is the most general and uses the relationships between the projection operators for the terms in the `formula` to decide which `projector`s to substract and which to orthogonalize using eigenmethods. The `differencing` option subtracts, from the current `projector`, those previously orthogonalized `projector`s for terms whose factors are a subset of the current `projector`'s factors. The `eigenmethods` option recursively orthogonalizes the `projector`s using an eigenanalysis of each `projector` with previously orthogonalized `projector`s.

`labels` A character nominating the type of labels to be used in labelling the projectors, and which will be used also in the output tables, such the tables of the aliasing in the structure. The two alternatives are `terms` and `sources`. Terms have all factors/variables in it separated by colons (`:`). Sources have factors/variables in them that represent interactions separated by hashes (#); if some factors are nested within others, the nesting factors are surrounded by square brackets (`[` and `]`) and separated by colons (`:`). If some generalized, or combined, factors have no marginal terms, the constituent factors are separated by colons (`:`) and if they interact with other factors in the source they will be parenthesized.

`marginality` A square matrix that can be used to supply the marginality matrix when it is desired to overwrite the calculated marginality matrix or when it is not being calculated. It should consist of zeroes and ones that gives the marginalites of the terms in the formula. It must have the row and column names set to the terms from the expanded `formula`, including being in the same order as these terms.

The entry in the ith row and jth column will be one if the ith term is marginal to the jth term i.e. the column space of the ith term is a subspace of that for the jth term and so the source for the jth term is to be made orthogonal to that for the ith term. Otherwise, the entries are zero. A row and column should not be included for the grand mean even if `grandMean` is `TRUE`.

`check.marginality`
A logical indicating whether the marginality matrix, when it is supplied, is to be checked against that computed by `pstructure.formula`. It is ignored when `orthogonalize` is set to `eigenmethods`.

`omit.projectors`
A logical, which, if `TRUE`, results in the projectors in the `Q` of the `pstructure.object` being replaced by their degrees of freedom. These will be the degrees of freedom of the sources. This option is included a device for saving storage when the projectors are not required for further analysis.

`which.criteria` A character `vector` nominating the efficiency criteria to be included in the summary of aliasing between terms. It can be `none`, `all` or some combination of `aefficiency`, `mefficiency`, `sefficiency`, `eefficiency`, `xefficiency`, `order` and `dforthog` – for details see `efficiency.criteria`. If `none`, no summary is printed.

`aliasing.print` A logical indicating whether the aliasing between sources within the structure is to be printed.

`data` A data frame contains the values of the factors and variables that occur in `formula`.

`...` further arguments passed to `terms`.

Details

Firstly, the primary projector $\mathbf{X}(\mathbf{X}'\mathbf{X})^{-}\mathbf{X}'$, where X is the design matrix for the term, is calculated for each term. Then each projector is made orthogonal to terms aliased with it using `porthogonalize.list`, either by `differencing`, `eigenmethods` or the default `hybrid` method.

`Differencing` relies on comparing the factors involved in two terms, one previous to the other, to identify whether to subtract the orthogonalized projector for the previous term from the primary projector of the other. It does so if factors/variables for the previous term are a subset of the factors/variablesfor for the other term. This relies on ensuring that all projectors whose factors/variables are a subset of the current projector occur before it in the expanded formula. It is checked that the set of matrices are mutually orthogonal. If they are not then a warning is given. It

may happen that differencing does not produce a projector, in which case `eigenmethods` must be used.

`Eigenmethods` forces each projector to be orthogonal to all terms previous to it in the expanded formula. It uses equation 4.10 of James and Wilkinson (1971), which involves calculating the canonical efficiency factors for pairs of primary projectors. It produces a table of efficiency criteria for partially aliased terms. Again, the order of terms is crucial. This method has the disadvantage that the marginality of terms is not determined and so sources names are set to be the same as the term names, unless a `marginality` matrix is supplied.

The `hybrid` method is the most general and uses the relationships between the projection operators for the terms in the `formula` to decide which projectors to subtract and which to orthogonalize using eigenmethods. If $\mathbf{Q}_i$ and $\mathbf{Q}_j$ are two projectors for two different terms, with $i < j$, then

1. if $\mathbf{Q}_j\mathbf{Q}_i \neq \mathbf{0}$ then have to orthogonalize $\mathbf{Q}_j$ to $\mathbf{Q}_i$.
2. if $\mathbf{Q}_j\mathbf{Q}_i = \mathbf{Q}_j$ then, if $\mathbf{Q}_i = \mathbf{Q}_j$, they are equal and $\mathbf{Q}_j$ will be removed from the list of terms; otherwise they are marginal and $\mathbf{Q}_i$ is subtracted from $\mathbf{Q}_j$.
3. if have to orthogonalize and $\mathbf{Q}_j\mathbf{Q}_i = \mathbf{Q}_i$ then $\mathbf{Q}_j$ is aliased with previous terms and will be removed from the list of terms; otherwise $\mathbf{Q}_i$ is partially aliased with $\mathbf{Q}_j$ and $\mathbf{Q}_j$ is orthogonalized to $\mathbf{Q}_i$ using eigenmethods.

The order of terms is crucial in this process.

Of the three methods, `eigenmethods` is least likely to fail, but it does not establish the marginality between the terms. It is often needed when there is nonorthogonality between terms, such as when there are several linear covariates. It can also be more efficeint in these circumstances.

The process can be computationally expensive, particularly for a large data set (500 or more observations) and/or when many terms are to be orthogonalized.

If the error `Matrix is not idempotent` should occur then, especially if there are many terms, one might try using `set.daeTolerance` to reduce the tolerance used in determining if values are either the same or are zero; it may be necessary to lower the tolerance to as low as 0.001. Also, setting `orthogonalize` to `eigenmethods` is worth a try.

Value

A `pstructure.object`.

Author(s)

Chris Brien

References

James, A. T. and Wilkinson, G. N. (1971) Factorization of the residual operator and canonical decomposition of nonorthogonal factors in the analysis of variance. *Biometrika*, **58**, 279-294.

See Also

`porthogonalize.list`, `proj2.efficiency`, `proj2.combine`, `proj2.eigen`, `projs.2canon` in package **dae**, `eigen`.

`projector` for further information about this class.

Examples

```
## PBIBD(2) from p. 379 of Cochran and Cox (1957) Experimental Designs.
## 2nd edn Wiley, New York
PBIBD2.unit <- list(Block = 6, Unit = 4)
PBIBD2.nest <- list(Unit = "Block")
trt <- factor(c(1,4,2,5, 2,5,3,6, 3,6,1,4, 4,1,5,2, 5,2,6,3, 6,3,4,1))
PBIBD2.lay <- designRandomize(allocated = trt,
                              recipient = PBIBD2.unit,
                              nested.recipients = PBIBD2.nest)
## manually obtain projectors for units
Q.G <- projector(matrix(1, nrow=24, ncol=24)/24)
Q.B <- projector(fac.meanop(PBIBD2.lay$Block) - Q.G)
Q.BP <- projector(diag(1, nrow=24) - Q.B - Q.G)

## manually obtain projector for trt
Q.T <- projector(fac.meanop(PBIBD2.lay$trt) - Q.G)

##compute intrablock efficiency criteria
effic <- proj2.efficiency(Q.BP, Q.T)
effic
efficiency.criteria(effic)

##obtain projectors using pstructure.formula
unit.struct <- pstructure(~ Block/Unit, data = PBIBD2.lay)
trt.struct <- pstructure(~ trt, data = PBIBD2.lay)

##obtain combined decomposition and summarize
unit.trt.p2canon <- projs.2canon(unit.struct$Q, trt.struct$Q)
summary(unit.trt.p2canon, which = c("aeff","eeff","order"))
```

`pstructure.object` *Description of a pstructure object*

Description

An object of class `pstructure` that contains information derived from a `formula` using `pstructure.formula`. It also inherits from class `list`.

Value

A `list` of class `pstructure` with the following components:

1. Q: a list with a component of class `projector`, being the orthogonalized projectors for each non-aliased term/source in the `formula`; if `grandMean` is `TRUE` in the call to `pstructure.formula` then it also includes the `projector` for it;
2. terms: a `character` vector with the non-aliased term names; if `grandMean` is `TRUE` in the call to `pstructure.formula` then the first term will be "`Mean`";
3. sources: a `character` vector with the non-aliased source names;
4. marginality: a `matrix` of zeroes and ones with the same number of rows and columns as number of non-aliased terms, excluding the term for the grand mean even when `grandMean` is `TRUE`; the row names and column names are the elements `terms`, excluding "`Mean`";

the entry in the ith row and jth column will be one if the ith term is marginal to the jth term i.e. the column space of the ith term is a subspace of that for the jth term and so the source for the jth term will have been made orthogonal to that for the ith term; otherwise, the entries are zero.

5. aliasing: a `data.frame` containing the information about the (partial) aliasing between the sources in the `formula`. The columns are:
   - Source: the source names, or associated term name, for those that are (partially) aliased with previous sources;
   - df: the remaining degrees of freedom for the source;
   - Alias: the source with which the current entry is (partially) aliased;
   - efficiency criteria: a set of columns for the complete set of criteria calculated by `efficiency.criteria`; the criteria reflect the amount of information that is aliased with previous sources and a line is included in the component that reports the informaton remaining after adjustment for previous sources.

   The information provided depends on the setting of `orthogonalize`. All the information is provided for the `"hybrid"` option. For the option `"differencing"`, no efficiency criteria are included and either the terms/sources of the `Alias` are set to `"unknown"` and the `df` are set to `NA` when these are unknown. For the option `"eigenmethods"`, the previous terms/sources cannot be identified and so all values of `Alias` are set to `NA`. If there is no (partial) aliasing then the component is set to `NULL`.

The object has the attribute `labels`, which is set to `"terms"` or `"sources"` according to which of these label the projectors.

Author(s)

Chris Brien

See Also

`pstructure.formula` and, for further information about the projector classs, `projector`.

`qqyeffects` *Half or full normal plot of Yates effects*

Description

Produces a half or full normal plot of the Yates effects from a 2^k factorial experiment.

Usage

```
qqyeffects(aov.obj, error.term="Within", data=NULL, pch=16,
           full=FALSE, ...)
```

Arguments

`aov.obj`	An `aov` object or `aovlist`object created from a call to `aov`.
`error.term`	The term from the `Error` function from which the Yates effects are estimated. Only required when `Error` used in call to `aov`.

data	A data.frame in which the variables specified in the aov.obj will be found. If missing, the variables are searched for in the standard way.
pch	The number of a plotting symbol to be drawn when plotting points (use help(points) for details).
full	whether a full or half normal plot is to be produced. The default is for a half-normal plot; full=TRUE produces a full normal plot.
...	Further graphical parameters may be specified (use help(par) for possibilities.

Details

A half or full normal plot of the Yates effects is produced. You will be able to interactively select effects to be labelled (click reasonably close to the point and on the side where you want the label placed). **Right click on the graph and select Stop when you have finished labelling effects.** A regression line fitted to the unselected effects and constrained to go through the origin is plotted. Also, a list of the labelled effects, if any, are printed to standard ouptut.

Value

Returns, invisibly, a list with components x and y, giving coordinates of the plotted points.

Author(s)

Chris Brien

See Also

yates.effects in package **dae**, qqnorm.

Examples

```
## analysis of 2^4 factorial experiment from Table 10.6 of Box, Hunter and
## Hunter (1978) Statistics for Experimenters. New York, Wiley.
## use ?Fac4Proc.dat for data set details
data(Fac4Proc.dat)
Fac4Proc.aov <- aov(Conv ~ Catal * Temp * Press * Conc + Error(Runs),
                                                        Fac4Proc.dat)
qqyeffects(Fac4Proc.aov, error.term="Runs", data=Fac4Proc.dat)
```

---

rep.data.frame *Replicate the rows of a data.frame by repeating each row consecutively and/or repeating all rows as a group*

Description

Replicate the rows of a data.frame by repeating each row consecutively and/or repeating all rows as a group.

Usage

```
## S3 method for class 'data.frame'
rep(x, times=1, each=1, ...)
```

Arguments

x	A data.frame whose rows are to be repeated.
times	The number of times to repeat the whole set of rows, after the rows have been replicated consecutively each times.
each	The number of times to replicate consecutively each row in the data.frame.
...	Further arguments passed to or from other methods. Unused at present.

Value

A data.frame with replicated rows.

Author(s)

Chris Brien

See Also

fac.gen in package **dae** and rep

Examples

```
rep(fac.gen(list(a = 2, b = 2)), times=2, each=2)
```

---

resid.errors *Extract the residuals for a fitted model*

Description

An alias for the generic function residuals. When it is available, the method residuals.aovlist extracts residuals, which is provided in the package **dae** to cover aovlist objects.

Usage

```
resid.errors(...)
```

Arguments

...	Arguments passed to residuals.aovlist.

Value

A numeric vector containing the residuals.

Note

See residuals.aovlist for specific information about the residuals when an Error function is used in the call to the aov function.

Author(s)

Chris Brien

See Also

fitted.errors, residuals.aovlist, tukey.1df in package **dae**.

Examples

```
## set up data frame for randomized complete block design in Table 4.4 from
## Box, Hunter and Hunter (2005) Statistics for Experimenters. 2nd edn
## New York, Wiley.
RCBDPen.dat <- fac.gen(list(Blend=5, Flask=4))
RCBDPen.dat$Treat <- factor(rep(c("A","B","C","D"), times=5))
RCBDPen.dat$Yield <- c(89,88,97,94,84,77,92,79,81,87,87,
                       85,87,92,89,84,79,81,80,88)

## perform the analysis of variance
RCBDPen.aov <- aov(Yield ~ Blend + Treat + Error(Blend/Flask), RCBDPen.dat)
summary(RCBDPen.aov)

## two equivalent ways of extracting the residuals
res  <- residuals.aovlist(RCBDPen.aov)
res <- residuals(RCBDPen.aov, error.term = "Blend:Flask")
res <- resid.errors(RCBDPen.aov)
```

---

residuals.aovlist *Extract the residuals from an aovlist object*

Description

Extracts the residuals from error.term or, if error.term is not specified, the last error.term in the analysis. It is a method for the generic function residuals.

Usage

```
## S3 method for class 'aovlist'
residuals(object, error.term=NULL, ...)
```

Arguments

object	An aovlist object created from a call to aov.
error.term	The term from the Error function for which the residuals are to be extracted. If error.term is NULL the residuals are extracted from the last Error term.
...	Further arguments passed to or from other methods.

Value

A numeric vector containing the residuals.

Author(s)

Chris Brien

See Also

fitted.errors, resid.errors, tukey.1df in package **dae**.

Examples

```
## set up data frame for randomized complete block design in Table 4.4 from
## Box, Hunter and Hunter (2005) Statistics for Experimenters. 2nd edn
## New York, Wiley.
RCBDPen.dat <- fac.gen(list(Blend=5, Flask=4))
RCBDPen.dat$Treat <- factor(rep(c("A","B","C","D"), times=5))
RCBDPen.dat$Yield <- c(89,88,97,94,84,77,92,79,81,87,87,
                       85,87,92,89,84,79,81,80,88)

## perform the analysis of variance
RCBDPen.aov <- aov(Yield ~ Blend + Treat + Error(Blend/Flask), RCBDPen.dat)
summary(RCBDPen.aov)

## two equivalent ways of extracting the residuals
res  <- residuals.aovlist(RCBDPen.aov)
res <- residuals(RCBDPen.aov, error.term = "Blend:Flask")
```

`rmvnorm` *generates a vector of random values from a multivariate normal distribution*

Description

Generates a vector of random values from an n-dimensional multivariate normal distribution whose mean is given by the n-vector `mean` and variance by the n x n symmetric matrix `V`. It uses the method described by Ripley (1987, p.98)

Usage

```
rmvnorm(mean, V, method = 'eigenanalysis')
```

Arguments

`mean`	The mean vector of the multivariate normal distribution from which the random values are to be generated.
`V`	The variance matrix of the multivariate normal distribution from which the random values are to be generated.
`method`	The method used to decompose the variance matrix in producing a a matrix to transform the iid standard normal values. The two methods available are `'eigenanalysis'` and `'choleski'`, where only the first letter of each option is obligatory. The default `method` is eigenanalysis, which is slower but is likely to be more stable than Choleski decomposition.

Details

The method is: a) uses either the eigenvalue or Choleski decomposition of the variance matrix, `V`, to form the matrix that transforms an iid vector of values to a vector with variance `V`; b) generate a vector of length equal to `mean` of standard normal values; c) premultiply the vector of standard normal values by the transpose of the upper triangular factor and, to the result, add `mean`.

Value

A `vector` of length n, equal to the length of `mean`.

Author(s)

Chris Brien

References

Ripley, B. D. (1987) *Stochastic simulation*. Wiley, New York.

See Also

fac.ar1mat, fac.vcmat, in package **dae**, rnorm, and chol.

Examples

```
## set up a two-level factor and a three-level factor, both of length 12
A <- factor(rep(1:2, each=6))
B <- factor(rep(1:3, each=2, times=2))

## generate random values from a multivariate normal for which
#the mean is 20 for all variables and
#the variance matrix has random effects for factor A, ar1 pattern for B and
#residual random variation
mean <- rep(20, 12)
V <- fac.vcmat(A, 5) + fac.ar1mat(B, 0.6) + 2*mat.I(12)
y <- rmvnorm(mean, V)
```

Sensory3Phase.dat *Data for the three-phase sensory evaluation experiment in Brien, C.J. and Payne, R.W. (1999)*

Description

The data is from an experiment involved two phases. In the field phase a viticultural experiment was conducted to investigate the differences between 4 types of trellising and 2 methods of pruning. The design was a split-plot design in which the trellis types were assigned to the main plots using two adjacent Youden squares of 3 rows and 4 columns. Each main plot was split into two subplots (or halfplots) and the methods of pruning assigned at random independently to the two halfplots in each main plot. The produce of each halfplot was made into a wine so that there were 24 wines altogether.

The second phase was an evaluation phase in which the produce from the halplots was evaluated by 6 judges all of whom took part in 24 sittings. In the first 12 sittings the judges evaluated the wines made from the halfplots of one square; the final 12 sittings were to evaluate the wines from the other square. At each sitting, each judge assessed two glasses of wine from each of the halplots of one of the main plots. The main plots allocated to the judges at each sitting were determined as follows. For the allocation of rows, each occasion was subdivided into 3 intervals of 4 consecutive sittings. During each interval, each judge examined plots from one particular row, these being determined using two 3x3 Latin squares for each occasion, one for judges 1-3 and the other for judges 4-6. At each sitting judges 1-3 examined wines from one particular column and judges 4-6 examined wines from another column. The columns were randomized to the 2 sets of judges x 3 intervals x 4 sittings using duplicates of a balanced incomplete block design for v=4 and k=2 that were latinized. This balanced incomplete block design consists of three sets of 2 blocks, each set containing the 4 "treatments". For each interval, a different set of 2 blocks was taken and each block assigned to two

sittings, but with the columns within the block placed in reverse order in one sitting compared to the other sitting. Thus, in each interval, a judge would evaluate a wine from each of the 4 columns.

The `data.frame` contains the following factors, in the order give: Occasion, Judges, Interval, Sittings, Position, Squares, Rows, Columns, Halfplot, Trellis, Method. They are followed by the simulated response variable Score.

The scores are ordered so that the factors Occasion, Judges, Interval, Sittings and Position are in standard order; the remaining factors are in randomized order.

See also the vignette accessed via `vignette("DesignNotes", package="dae")`.

Usage

```
data(Sensory3Phase.dat)
data(Sensory3PhaseShort.dat)
```

Format

A data.frame containing 576 observations of 12 variables. There are two versions, one with shorter factor names than the other.

References

Brien, C.J. and Payne, R.W. (1999) Tiers, structure formulae and the analysis of complicated experiments. *The Statistician*, **48**, 41-52.

`set.daeTolerance` *Sets the values of daeTolerance for the package dae*

Description

A function that sets the values such that, in **dae** functions, values less than it are considered to be zero. The values are stored in a `vector` named `daeTolerance` in the `daeEnv` environment. The `vector` is of length two and, initially, both values are set to `.Machine$double.eps ^ 0.5` (about 1.5E-08). One value is named `element.tol` and is used for elements of matrices; the second is named `element.eigen` and is used for eigenvalues and quantities based on them, such as efficiency factors.

Usage

```
set.daeTolerance(element.tol=NULL, eigen.tol=NULL)
```

Arguments

`element.tol`	The value to to which the first element of the `daeTolerance` `vector` is to be set. If more than one value is supplied, only the first value is used.
`eigen.tol`	The value to to which the second element of the `daeTolerance` `vector` is to be set. If more than one value is supplied, only the first value is used.

Value

The `vector` `daeTolerance` is returned invisibly.

Author(s)

Chris Brien

See Also

get.daeTolerance.

Examples

```
## set daeTolerance.
set.daeTolerance(1E-04, 1E-08)
```

---

show-methods *Methods for Function show in Package dae*

Description

Methods for function show in Package **dae**

Methods

signature(object = "projector") Prints the matrix and its degrees of freedom.

See Also

projector for further information about this class.

SPLGrass.dat *Data for an experiment to investigate the effects of grazing patterns on pasture composition*

Description

The response variable is the percentage area covered by the principal grass (Main.Grass). The design for the experiment is a split-unit design. The main units are arranged in 3 Rows x 3 Columns. Each main unit is split into 2 SubRows x 2 SubColumns.

The factor Period, with levels 3, 9 and 18 days, is assigned to the main units using a 3 x 3 Latin square. The two-level factors Spring and Summer are assigned to split-units using a criss-cross design within each main unit. The levels of each of Spring and Summer are two different grazing patterns in its season.

Usage

```
data(SPLGrass.dat)
```

Format

A data.frame containing 36 observations of 8 variables.

Source

Example 14.1 from Mead, R. (1990). *The Design of Experiments: Statistical Principles for Practical Application.* Cambridge, Cambridge University Press.

`strength` *Generate paper strength values*

Description

Generates paper strength values for an experiment with different temperatures.

Usage

```
strength(nodays, noruns, temperature, ident)
```

Arguments

`nodays`	The number of days over which the experiment is to be run.
`noruns`	The number of runs to be performed on each day of the experiment.
`temperature`	A `factor` that encapsulates the layout by giving the temperature to be investigated for each run on each day. These must be ordered so that the temperatures for the first day are given in the order in which they are to be investigated on that day. These must be followed by the noruns temperatures for the second day and so on. Consequently, the factor temperature will have nodays*noruns values.
`ident`	The digits of your student identity number. That is, leave out any letters.

Value

A `data.frame` object containing the `factors` day, run and temperature and a `vector` of the generated strengths.

Author(s)

Chris Brien

Examples

```
## Here temperature is a factor with 4*3 = 12 values whose
## first 3 values specify the temperatures to be applied in
## the 3 runs on the first day, values 4 to 6 specify the
## temperatures for the 3 runs on day 2, and so on.
temperature <- factor(rep(c(80,85,90), 4))
exp.strength <- strength(nodays = 4, noruns = 3,
                         temperature = temperature, ident = 0123456)

## In this second example, a completely randomized design is generated
## for the same 3 temperatures replicated 4 times. The layout is stored
## in the data.frame called Design.
Design <- designRandomize(allocated = temperature,
                          recipient = list(runs = 12),
                          seed = 5847123)
## eradicate the unrandomized version of temperature
```

```
remove("temperature")

## The 12 temperatures in Design are to be regarded as being assigned to
## days and runs in the same manner as for the first example.
exp.strength <- strength(nodays = 4, noruns = 3,
                         temperature = Design$temperature, ident = 0123456)
```

---

summary.p2canon *Summarize a canonical analysis of the relationships between two sets of projectors*

Description

Produces a summary of the efficiency criteria computed from the canonical efficiency factors for the joint decomposition of two sets of projectors (Brien and Bailey, 2009) obtained using projs.2canon. It takes the form of a decomposition or skeleton ANOVA table.

Usage

```
## S3 method for class 'p2canon'
summary(object, which.criteria = c("aefficiency", "eefficiency", "order"), ...)
```

Arguments

object	A list of class p2canon produced by projs.2canon.
which.criteria	A character vector nominating the efficiency criteria to be included in the summary. It can be none, all or some combination of aefficiency, mefficiency, sefficiency, eefficiency, xefficiency, order and dforthog – for details see efficiency.criteria.
...	further arguments affecting the summary produced.

Value

An object of classes summary.p2canon and data.frame, whose rows correspond to the pairs of projectors, one from the Q1 argument and the other from the Q2 argument from projs.2canon; only pairs with non-zero efficiency factors are included. In addition, a line is included for each nonzero Residual Q1 projector.

Author(s)

Chris Brien

References

Brien, C. J. and R. A. Bailey (2009). Decomposition tables for multitiered experiments. I. A chain of randomizations. *The Annals of Statistics*, **36**, 4184 - 4213.

See Also

projs.2canon, proj2.efficiency, efficiency.criteria, proj2.combine, proj2.eigen, pstructure, print.summary.p2canonin package **dae**, eigen.

projector for further information about this class.

Examples

```
## PBIBD(2) from p. 379 of Cochran and Cox (1957) Experimental Designs.
## 2nd edn Wiley, New York
PBIBD2.unit <- list(Block = 6, Unit = 4)
PBIBD2.nest <- list(Unit = "Block")
trt <- factor(c(1,4,2,5, 2,5,3,6, 3,6,1,4, 4,1,5,2, 5,2,6,3, 6,3,4,1))
PBIBD2.lay <- designRandomize(allocated = trt,
                              recipient = PBIBD2.unit,
                              nested.recipients = PBIBD2.nest)

##obtain projectors using pstructure
unit.struct <- pstructure(~ Block/Unit, data = PBIBD2.lay)
trt.struct <- pstructure(~ trt, data = PBIBD2.lay)

##obtain combined decomposition and summarize
unit.trt.p2canon <- projs.2canon(unit.struct$Q, trt.struct$Q)
summary(unit.trt.p2canon)
```

`summary.pcanon` *Summarizes the anatomy of a design, being the decomposition of the sample space based on its canonical analysis, as produced by designAnatomy*

Description

Gives the anatomy of a design in a table; it summarizes the joint decomposition of two or more sets of projectors (Brien and Bailey, 2009) obtained using `designAnatomy`. It includes the efficiency criteria computed from the canonical efficiency factors for the joint decomposition. The labels in the table may be Terms or Sources. The terms are those that would be included in a mixed model for an experiment based on the design. The sources are the orthogonal subspaces, derived from the terms, that make up the decomposition and the degrees of freedom and efficiency factors relate to these subspaces. The table displays how the information for the different sources allowed for in the design are related. For more information about the notation used for sources see the `labels` argument of `designAnatomy`.

It is possible to supply an `object` that is a `pcanon.object` produced in versions prior to 3.0-0 using `projs.canon`.

Usage

```
## S3 method for class 'pcanon'
summary(object, labels.swap = FALSE,
        which.criteria = c("aefficiency", "eefficiency", "order"), ...)
```

Arguments

`object`	A `pcanon.object`.
`labels.swap`	A `logical` indicating whether to swap between "sources" and 'terms' in the output. The default is established by the `labels` argument of `designAnatomy` and `projs.canon`.

`which.criteria` A `character` `vector` nominating the efficiency criteria to be included in the summary. It can be `none`, `all` or some combination of `aefficiency`, `mefficiency`, `sefficiency`, `eefficiency`, `xefficiency`, `order` and `dforthog` – for details see `efficiency.criteria`. If there is only one formula, this argument is ignored.

`...` further arguments affecting the summary produced.

Value

An object of class `summary.pcanon` that is a `list` with the two components `decomp` and `aliasing`.

The component `decomp` is a `data.frame` whose rows correspond to subspaces in the decomposition for a design. It has the following `attributes`: (i) `title` that is the title for printing with the decomposition table; (ii) `ntiers` that is equal to the number of tiers; (iii) `orthogonal` that is `TRUE` if the design is orthogonal; (iv) `labels` that is either "terms" or "sources" depending on the `labels` that have resulted from the setting of `label.swap`.

The component `aliasing` is a `data.frame` that is also of `class` `aliasing`. It contains information about the aliasing between terms that are derived from the same formula and has the attribute `title` that is the title to be printed with the aliasing table.

However, if the `object` supplied is a `pcanon.object` produced with versions prior to 3.0-0 using `projs.canon`, the value is a `data.frame`, instead of a `list`, that has the same `attributes` as the `decomp` component of the `summary.pcanon` object now produced, except that `labels` is always set to "terms".

Author(s)

Chris Brien

References

Brien, C. J. and R. A. Bailey (2009). Decomposition tables for multitiered experiments. I. A chain of randomizations. *The Annals of Statistics*, **36**, 4184 - 4213.

See Also

`designAnatomy`, `designAnatomy`, , `pstructure`, `efficiency.criteria`, `proj2.combine`, `proj2.efficiency`, `proj2.eigen`, `print.summary.pcanon`in package **dae**, `eigen`.

`projector` for further information about this class.

Examples

```
## PBIBD(2) from p. 379 of Cochran and Cox (1957) Experimental Designs.
## 2nd edn Wiley, New York
PBIBD2.unit <- list(Block = 6, Unit = 4)
PBIBD2.nest <- list(Unit = "Block")
trt <- factor(c(1,4,2,5, 2,5,3,6, 3,6,1,4, 4,1,5,2, 5,2,6,3, 6,3,4,1))
PBIBD2.lay <- designRandomize(allocated = trt,
                              recipient = PBIBD2.unit,
                              nested.recipients = PBIBD2.nest)

##obtain combined decomposition and summarize
unit.trt.canon <- designAnatomy(list(unit=~ Block/Unit, trt=~ trt),
                                data = PBIBD2.lay)
summary(unit.trt.canon, which = c("aeff","eeff","order"))
summary(unit.trt.canon, which = c("aeff","eeff","order"), labels.swap = TRUE)
```

tukey.1df *Performs Tukey's one-degree-of-freedom-test-for-nonadditivity*

Description

Performs Tukey's one-degree-of-freedom-test-for-nonadditivity on a set of residuals from an analysis of variance.

Usage

```
tukey.1df(aov.obj, data, error.term="Within")
```

Arguments

aov.obj	An aov object or aovlist object created from a call to aov.
error.term	The term from the Error function whose residuals are to be tested for nonadditivity. Only required when the Error function used in call to aov, so that an aovlist object is created.
data	A data.frame containing the original response variable and factors used in the call to aov.

Value

A list containing Tukey.SS, Tukey.F, Tukey.p, Devn.SSq being the SSq for the 1df test, F value for test and the p-value for the test.

Note

In computing the test quantities fitted values must be obtained. If error.term is specified, fitted values will be the sum of effects extracted from terms from the Error function, but only down to that specified by error.term.The order of terms is as given in the ANOVA table. If error.term is unspecified, all effects for terms external to any Error terms are extracted and summed.

Extracted effects will only be for terms external to any Error function. If you want effects for terms in the Error function to be included, put them both inside and outside the Error function so they are occur twice.

Author(s)

Chris Brien

See Also

fitted.errors, resid.errors in package **dae**.

Examples

```
## set up data frame for randomized complete block design in Table 4.4 from
## Box, Hunter and Hunter (2005) Statistics for Experimenters. 2nd edn
## New York, Wiley.
RCBDPen.dat <- fac.gen(list(Blend=5, Flask=4))
RCBDPen.dat$Treat <- factor(rep(c("A","B","C","D"), times=5))
RCBDPen.dat$Yield <- c(89,88,97,94,84,77,92,79,81,87,87,
```

```
                    85,87,92,89,84,79,81,80,88)

## perform the analysis of variance
RCBDPen.aov <- aov(Yield ~ Blend + Treat + Error(Blend/Flask), RCBDPen.dat)
summary(RCBDPen.aov)

## Obtain the quantities for Tukey's test
tukey.1df(RCBDPen.aov, RCBDPen.dat, error.term = "Blend:Flask")
```

`yates.effects` *Extract Yates effects*

Description

Extracts Yates effects from an `aov` object or `aovlist` object.

Usage

```
yates.effects(aov.obj, error.term="Within", data=NULL)
```

Arguments

`aov.obj`	An `aov` object or `aovlist` object created from a call to `aov`.
`error.term`	The term from the `Error` function from which the Yates effects are estimated. Only required when `Error` used in call to `aov`.
`data`	A `data.frame` in which the variables specified in the `aov.obj` will be found. If missing, the variables are searched for in the standard way.

Details

Yates effects are specific to 2^k experiments, where Yates effects are conventionally defined as the difference between the upper and lower levels of a factor. We follow the convention used in Box, Hunter and Hunter (1978) for scaling of higher order interactions: all the Yates effects are on the same scale, and represent the average difference due to the interaction between two different levels. Effects are estimated only from the error term supplied to the `error.term` argument.

Value

A `vector` of the Yates effects.

Author(s)

Chris Brien

See Also

`qqyeffects` in package **dae**, `aov`.

Examples

```
## analysis of 2^4 factorial experiment from Table 10.6 of Box, Hunter and
## Hunter (1978) Statistics for Experimenters. New York, Wiley.
## use ?Fac4Proc.dat for data set details
data(Fac4Proc.dat)
Fac4Proc.aov <- aov(Conv ~ Catal * Temp * Press * Conc + Error(Runs),
                                                        Fac4Proc.dat)
round(yates.effects(Fac4Proc.aov, error.term="Runs", data=Fac4Proc.dat), 2)
```

`Zncsspline` *Calculates the design matrix for fitting the random component of a natural cubic smoothing spline*

Description

Calculates the design matrix, $\mathbf{Z}$, of the random effects for a natural cubic smoothing spline as described by Verbyla et al., (1999). An initial design matrix, $\mathbf{\Delta}\mathbf{\Delta}^{-1}\mathbf{\Delta}$, based on the knot points is computed. It can then be post multiplied by the power of the tri-diagonal matrix $\boldsymbol{G}_s$ that is proportional to the variance matrix of the random spline effects. If the power is set to 0.5 then the random spline effects based on the resulting Z matrix will be independent with variance σ^2_s.

Usage

```
Zncsspline(knot.points, Gpower = 0, print = FALSE)
```

Arguments

`knot.points`	A `numeric` giving the values of the knot points to be used in fitting the spline. These must be orderd in increasing order.
`Gpower`	A `numeric` giving the power of the tri-diagonal matrix $\boldsymbol{G}_s$ from which the variance matrix of the random spline effects is caluclated. that the initial design matrix is to be the value of the variance component for the random spline effects. The smoothing parameter is then the inverse of the ratio of this component to the residual variance.
`print`	A `logical` indicating whether to print the $\mathbf{\Delta}$ and $\boldsymbol{G}_s$ matrices.

Value

A `matrix` containing the design matrix.

Author(s)

Chris Brien

References

Verbyla, A. P., Cullis, B. R., Kenward, M. G., and Welham, S. J. (1999). The analysis of designed experiments and longitudinal data by using smoothing splines (with discussion). *Journal of the Royal Statistical Society, Series C (Applied Statistics)*, **48**, 269-311.

See Also

mat.ncssvar.

Examples

```
Z <- Zncsspline(knot.points = 1:10, Gpower = 0.5)
```

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