Package ‘cherry’

June 22, 2015

Version 0.6-11
Date 2015-06-19
Title Multiple Testing Methods for Exploratory Research
Author Jelle Goeman, Aldo Solari, Rosa Meijer
Maintainer Jelle Goeman <jelle.goeman@radboudumc.nl>
Depends methods, bitops, lpSolve, Matrix, slam
Imports MASS, multtest, gurobi
Description Provides an alternative approach to multiple testing
by calculating a simultaneous upper confidence bounds for the
number of true null hypotheses among any subset of the hypotheses of interest.
Some of the functions in this package are optionally enhanced by the 'gurobi'
software and its accompanying R package. For their installation, please follow the
instructions at www.gurobi.com and http://www.gurobi.com/documentation, respectively.
License GPL (>= 2)
DAGstructure.R structuredHolm.R
LazyLoad yes
Repository CRAN
NeedsCompilation no
Date/Publication 2015-06-22 19:53:18

R topics documented:

- Adjusted ................................................. 2
- Closed Testing ........................................... 3
- Closure class ............................................ 5
- Construct the DAG from a given collection of sets. ....... 6
- DAG class ................................................. 7
- DAG Testing ............................................... 9
- DAGpick .................................................. 12
Adjusted

Adjusted p-values for the number of true hypotheses.

Description

Calculates adjusted p-values for the number of true hypotheses on the basis of the closed testing procedure.

Usage

adjusted (closure, reject, n=0)

Arguments

closure An object of class closure, typically created through a call to closed.
reject A character vector identifying the hypotheses to be rejected. Must be a subvector of hypotheses(closure).
n The maximum number of false null hypotheses allowed.

Details

The function pick calculates adjusted p-values for intersection hypotheses of interest.

Value

The function returns a p-value (numeric).

Author(s)

Jelle Goeman: <j.j.goeman@lumc.nl>
Examples

# Example: the birthwt data set from the MASS library
# We want to find variables associated with low birth weight
library(MASS)
fullfit <- glm(low~age+lwt+race+smoke+ptl+ht+ui+ftv, family=binomial, data=birthwt)
hypotheses <- c("age", "lwt", "race", "smoke", "ptl", "ht", "ui", "ftv")

# Define the local test to be used in the closed testing procedure
mytest <- function(hyps) {
  others <- setdiff(hypotheses, hyps)
  form <- formula(paste(c("low-", paste(c("1", others), collapse="+")))))
  anov <- anova(glm(form, data=birthwt, family=binomial), fullfit, test="Chisq")
  res <- anov$Pr("[2]" ) # for R >= 2.14.0
  if (is.null(res)) res <- anov$"P( [2]" # earlier versions
  res
}

# Perform the closed testing with adjusted p-values
cl <- closed(mytest, hypotheses, alpha=NA)

# What is the adjusted p-value of the intersection of the following hypotheses?
adjusted(cl, c("ht", "lwt", "smoke", "ui"))

# From what confidence level would we conclude that more than 2 of the following hypotheses would be false?
adjusted(cl, c("ht", "lwt", "smoke", "ui"), n=2)

---

Closed Testing for Exploratory Research

Description

Performs the closed testing procedure for user-specified local test.

Usage

closed (test, hypotheses, alpha = 0.05, adjust=FALSE)

Arguments

test A function that performs the local test. The function should accept a subvector of the hypotheses argument as input, and return a p-value.

hypotheses Identifiers of the collection of elementary hypotheses.

alpha The significance level of the test procedure. If set to NA, the function calculates adjusted p-values for each hypothesis in the closure.

adjust Whether adjusted p-values should be calculated.
Details

The function closed performs the closed testing procedure on the collection hypotheses, testing all their intersection hypotheses and controlling the familywise error rate.

Value

The function closed returns an object of class closure.

Note

The number of intersection hypotheses is exponential in the number of elementary hypotheses. The number of elementary hypotheses is therefore limited to \( \log_2(\text{Machine} \times \text{integer.max} + 1) \) (typically 31) for computational reasons.

It is possible to set both adjust to TRUE and specify alpha. In that case, adjusted p-values are calculated up to a value alpha; all higher p-values are set to 1.

Author(s)

Jelle Goeman: <j.j.goeman@lumc.nl>

References


Examples

```r
# Example: the birthwt data set from the MASS library
# We want to find variables associated with low birth weight
library(MASS)
fullfit <- glm(low~age+lwt+race+smoke+ptl+ht+ui+ftv, family=binomial, data=birthwt)
hypotheses <- c("age", "lwt", "race", "smoke", "ptl", "ht", "ui", "ftv")

# Define the local test to be used in the closed testing procedure
mytest <- function(hyps) {
  others <- setdiff(hypotheses, hyps)
  form <- formula(paste(c("low=" , paste(c("1", others), collapse="+")))))
  anov <- anova(glm(form, data=birthwt, family=binomial), fullfit, test="Chisq")
  res <- anov$Pr("
  if (is.null(res)) res <- anov$$Pr("

# perform the closed testing
cl <- closed(mytest, hypotheses)
c1

# how many variables among a chosen set are associated with the response?
pick(cl, c("ht", "lwt", "smoke", "ui"))

# adjusted p-values and a confidence distribution
cl <- closed(mytest, hypotheses, alpha=NA)
```
Closure class

Class "closure" for storing the result of the closed testing procedure

Description

The class closure is the output of a call to 

\texttt{closed}. It stores the information needed to calculate confidence sets for the number of true and/or false hypotheses among a selected set.

Slots

These slots are not meant to be directly accessed by the user.

\begin{itemize}
    \item \texttt{adjusted}: Object of class "numeric". Serves the adjusted p-values.
    \item \texttt{defining}: Object of class "integer". Stores the identifiers of the intersection hypotheses that are the defining rejections of the closed testing procedure. The identifiers should be read as binary booleans, i.e. 19 = 10011 (binary) is the intersection of the first, second and fifth elementary hypothesis.
    \item \texttt{hypotheses}: Object of class "character". Holds the names of the elementary hypotheses.
    \item \texttt{alpha}: Object of class "numeric". The type I error level chosen.
    \item \texttt{max.alpha}: Object of class "numeric". The largest value for which adjusted p-values have been calculated.
\end{itemize}

Methods

\begin{itemize}
    \item \texttt{show (closure)}: Prints a brief description of the test results, including the upper bound of the number of true hypotheses and the corresponding lower bound to the number of false hypotheses among the full set.
    \item \texttt{summary (closure)}: Prints the test results (as \texttt{show}) plus the defining rejections.
    \item \texttt{defining (closure)}: Extracts the defining rejections as a list.
    \item \texttt{shortlist (closure)}: Extracts the shortlist as a list.
    \item \texttt{hypotheses (closure)}: Extracts the hypotheses slot.
\end{itemize}

Author(s)

Jelle Goeman: \texttt{<j.j.goeman@lumc.nl>}

See Also

\texttt{closed, pick}.
Construct the DAG from a given collection of sets.

Description

Constructs a DAG from a given collection of sets. Filters duplicates, and checks whether the eventual DAG structure has two-way logical relationships.

Usage

\[
\text{construct(sets)}
\]

Arguments

\[
\text{sets} \quad \text{A list of sets/hypotheses for which you want to construct a DAG according to the underlying subset relations.}
\]

Value

The function construct returns an object of class \text{DAGstructure}. 

Examples

# Example: the birthwt data set from the MASS library
# We want to find variables associated with low birth weight
library(MASS)
fullfit <- glm(low~age+lwt+race+smoke+ptl+ht+ui+ftv, family=binomial, data=birthwt)
hypotheses <- c("age", "lwt", "race", "smoke", "ptl", "ht", "ui", "ftv")

# Define the local test to be used in the closed testing procedure
mytest <- function(hyps) {
  others <- setdiff(hypotheses, hyps)
  form <- formula(paste(c("low=" , paste(c("1", others), collapse="+"))))
  anov <- anova(glm(form, data=birthwt, family=binomial), fullfit, test="Chisq")
  res <- anov$"Pr"[2] # for R >= 2.14.0
  if (is.null(res)) res <- anov$"P"[2] # earlier versions
  res
}

# perform the closed testing procedure
cl <- closed(mytest, hypotheses)
summary(cl)
defining(cl)
shortlist(cl)
hypotheses(cl)

# how many variables among a chosen set are associated with the response?
pick(cl, c("ht", "lwt", "smoke", "ui"))
**DAG class**

**Author(s)**
Rosa Meijer: <r.j.meijer@lumc.nl>

**See Also**
DAGstructure

**Examples**

```r
# Generate data, where the response Y is associated with two (out of 4) covariates
set.seed(1)
n <- 100
p <- 4
X <- matrix(rnorm(n*p), n, p)
beta <- c(0, 0.5, 0.5, 0)
y <- X %*% beta + rnorm(n)

# Let us assume we have the following sets that we want to test:
sets <- list(c(1, 2, 3, 4), c(1, 2), c(2, 3, 4), c(2, 3), 1, 2, 3, 4)
names(sets) <- c(1234, 12, 234, 23, 1, 2, 3, 4)

# Start by making the corresponding graph structure
struct <- construct(sets)

# Check whether the DAG has toway logical relations:
istwoway(struct)
```

---

**DAG class**  

**Class "DAG" for storing the result of the DAG multiple testing method**

**Description**

The class DAG is the output of a call to DAGmethod. It stores which hypotheses have been rejected and can be used to calculate confidence sets for the number of true and/or false hypotheses among a selected set of hypotheses.

**Slots**

These slots are not meant to be directly accessed by the user.

- **sets**: Object of class "list". Stores unique original sets that are to be tested.
- **method**: Object of class "character". Stores whether the any-parent, all-parents or structuredHolm method has been used.
- **isadjusted**: Object of class "logical". Stores whether adjusted p-values are calculated.
- **allpvalues**: Object of class "numeric". Stores (adjusted) p-values for all hypotheses. Has value NA if adjusted p-value is larger than alpha.
implications: Object of class "logical". Stores whether hypotheses are implications at chosen alpha-level
alpha: Object of class "numeric". The type I error level chosen.
rejected: Object of class "logical". Stores for each hypothesis whether this hypothesis has been rejected
leaf_based_sets: Object of class "list". Stores sets expressed in the indices of their corresponding leaf nodes (which are sets themselves).
twoway: Object of class "logical". Is TRUE if the final DAG structure has twoway logical relationships.

Methods
show (DAG): Prints how many hypotheses there are in total and how many of them were rejected.
summary (DAG): Prints the test results (as show).
alpha (DAG): Retrieves the maximal alpha_value from the DAG object.
implications (DAG): Retrieves the implications from a given DAG object.
pvalue (DAG, indicator): Retrieves pvalues for all possible hypotheses (as specified by indicator) from the DAG object.

Author(s)
Rosa Meijer: <r.j.meijer@lumc.nl>

See Also
DAGmethod, DAGpick, structuredHolm.

Examples

#Generate data, where the response Y is associated with two (out of 4) covariates
set.seed(1)
N=100
p=4
X <- matrix(rnorm(n*p),n,p)
beta <- c(0,0.5,0.5,0)
Y <- X %*% beta + rnorm(n)

# Let us assume we have the following sets that we want to test:
sets <- list(c(1,2,3,4), c(1,2), c(2,3,4), c(2,3), 1, 2, 3, 4)
names(sets) <- c(1234, 12, 234, 23, 1, 2, 3, 4)

# Start by making the corresponding graph structure
struct <- construct(sets)

# Check whether the DAG has twoway logical relations:
istwoway(struct)

# Define the local test to be used in the closed testing procedure.
# This test expects a set as input.
mytest <- function(set)
{
  X <- X[, set, drop=FALSE]
  lm.out <- lm(Y ~ X)
  x <- summary(lm.out)
  return(pf(x$fstatistic[1],x$fstatistic[2],x$fstatistic[3],lower.tail=FALSE))
}

# Perform the DAG procedure (default is all-parents method).
DAG <- DAGmethod(struct, mytest, isadjusted=TRUE)
summary(DAG)

# What are the smallest sets that are found to be significant? If the sets have names,
# as in our example, the `implications` function will return the names
# of the implying sets, together with their (adjusted) p-value.
# If no names are provided, indices will be used instead of the names.
implications(DAG)

# What is the adjusted p-value of the null-hypothesis corresponding to the fourth set,
# which is set c(2,3)?
# To look up the pvalue, the function uses the index or name of the set
# in the list of sets stored in the DAGstructure.
# (Note that, if there were duplicate sets in the original list, this index can be different from
# the one in the original list given to `construct`)
pvalue(DAG,4)
pvalue(DAG, "23") # as above, but while using names

# How many of the elementary hypotheses (the last 4 sets) have to be false
# with probability 1-\alpha?  
# Sets (don't have to be elementary hypotheses in general) must be specified
# by their index or name.
DAGpick(DAG, 5:8)
DAGpick(DAG, c("1","2","3","4")) # as above, but while using names

---

**DAG Testing**

Testing of hypotheses, forming a DAG.

**Description**

Tests all hypotheses in a given DAG while controlling the FWER, using a user-specified local test.

**Usage**

DAGmethod(DAGstructure, test, alpha_max = 0.05, method = "all", isadjusted = FALSE,
          optimization = "none", degree = "group", pvalues = NULL, verbose = FALSE)
**Arguments**

- **DAGstructure**: DAGstructure object, as returned by the function `construct`.
- **test**: A function that performs the local test. The function should have a set as input and return a p-value.
- **alpha_max**: The significance level of the test procedure.
- **method**: Type of DAG procedure that is chosen. "all" gives the all-parents procedure, "any" the any-parent procedure.
- **isadjusted**: If set to TRUE, adjusted p-values will be calculated. Otherwise, the p-values of all rejected hypotheses will equal alpha_max.
- **optimization**: Can be, in ascending order of accuracy and computational costs: "none", "LP" (linear programming) or "ILP" (integer linear programming).
- **degree**: Can be "group" or "individual". If "group" is chosen, optimization is done on a group level, otherwise on an individual level (more accurate, but more time-consuming).
- **pvalues**: Optional (in case of stored p-values): a vector in which the raw p-values of the exact sets as found in the DAGstructure argument are stored (in the same order). If the test function is provided, this argument is not necessary.
- **verbose**: If set to TRUE, while running the method, a counter will indicate how many hypotheses are already rejected.

**Details**

The function `dagmethod` tests all possible hypotheses within a given DAG structure, while controlling the familywise error rate.

**Value**

The function `dagmethod` returns an object of class `DAG`.

**Author(s)**

Rosa Meijer: <r.j.meijer@lumc.nl>

**References**


**See Also**

`DAG, DAGstructure, construct, DAGpick`. 
Examples

```r
# Generate data, where the response Y is associated with two (out of 4) covariates
set.seed(1)
n <- 100
p <- 4
X <- matrix(rnorm(n*p), n, p)
beta <- c(0.0, 0.5, 0.5, 0)
Y <- X %*% beta + rnorm(n)

# Let us assume we have the following sets that we want to test:
sets <- list(c(1,2,3,4), c(1,2), c(2,3,4), c(2,3), 1, 2, 3, 4)
names(sets) <- c(1234, 12, 234, 23, 1, 2, 3, 4)

# Start by making the corresponding graph structure
struct <- construct(sets)

# Check whether the DAG has toway logical relations:
istwoway(struct)

# Define the local test to be used in the closed testing procedure.
# This test expects a set as input.
mytest <- function(set)
{
  X <- X[set, drop=FALSE]
  lm.out <- lm(Y ~ X)
  x <- summary(lm.out)
  return(pf(x$fstatistic[1], x$fstatistic[2], x$fstatistic[3], lower.tail=FALSE))
}

# Perform the DAG procedure (default is all-parents method).
DAG <- DAGmethod(struct, mytest, isadjusted=TRUE)
summary(DAG)

# What are the smallest sets that are found to be significant?
implications(DAG)

# What is the adjusted p-value of the null-hypothesis corresponding to the fourth set,
# which is set c(2,3)?
# To look up the pvalue, the function uses the index or name of the set
# in the list of sets stored in the DAGstructure.
# (Note that, if there were duplicate sets in the original list, this index can be different from
# the one in the original list given to `construct()`) pvalue(DAG,4)
# pvalue(DAG, "23") # as above, but while using names

# How many of the elementary hypotheses (the last 4 sets) have to be false
# with probability 1-alpha?
# Sets (don't have to be elementary hypotheses in general) must be specified
# by their index or name.
DAGpick(DAG, 5:8)
DAGpick(DAG, c("1","2","3","4")) # as above, but while using names
```
**DAGpick**

**Confidence limits for the number of false hypotheses in a given family of sets.**

**Description**
Calculates confidence limits for the number of false hypotheses on the basis of the DAG procedure within a family of sets.

**Usage**

```
DAGpick (DAG, indicators, optimization = "ILP")
```

**Arguments**

- **DAG**
  - DAG object, as returned by the function `DAGmethod`.

- **indicators**
  - The names or indices of the sets (as specified in the DAGstructure object) for which you want to know the confidence limits. Note that, if there were duplicate sets in the original list, the index can be different from the one in the original list given to construct.

- **optimization**
  - Can be, in ascending order of accuracy and computational costs: "LP" (linear programming) or "ILP" (integer linear programming).

**Value**
The function `DAGpick` returns the lower bound of a 1-alpha confidence set for the number of false sets. For the moment, the function can only be used on DAG objects that correspond to a DAG with two-way logical relationships.

**Author(s)**
Rosa Meijer: <r.j.meijer@lumc.nl>

**See Also**
`DAGmethod, DAG`.

**Examples**

```r
#Generate data, where the response Y is associated with two (out of 4) covariates
set.seed(1)
n=100
p=4
X <- matrix(rnorm(n*p),n,p)
beta <- c(0,0.5,0.5,0)
```
Y <- X %*% beta + rnorm(n)

# Let us assume we have the following sets that we want to test:
sets <- list(c(1,2,3,4), c(1,2), c(2,3,4), c(2,3), 1, 2, 3, 4)
names(sets) <- c(1234, 12, 234, 23, 1, 2, 3, 4)

# Start by making the corresponding graph structure
struct <- construct(sets)

# Define the local test to be used in the closed testing procedure.
# This test expects a set as input.
mytest <- function(set)
{
  X <- X[,set,drop=FALSE]
  lm.out <- lm(Y ~ X)
  x <- summary(lm.out)
  return(pf(x$fstatistic[1],x$fstatistic[2],x$fstatistic[3],lower.tail=FALSE))
}

# Perform the DAG procedure (default is all-parents method).
DAG <- DAGmethod(struct, mytest, isadjusted=TRUE)
summary(DAG)

# How many of the elementary hypotheses (the last 4 sets) have to be false
# with probability 1-alpha?
# Sets (don't have to be elementary hypotheses in general) must be specified
# by their index or name.
DAGpick(DAG, 5:8)
DAGpick(DAG, c("1","2","3","4")) # as above, but while using names

---

**DAGstructure class**  
Class "DAGstructure" for storing the result of the construct method that constructs the DAG.

---

**Description**

The class DAGstructure is the output of a call to `construct`. It stores the DAG structure that is induced by the given sets.

**Slots**

These slots are not meant to be directly accessed by the user.

- `parents`: Object of class "list". Stores the parents of each set, indicated by indices.
- `children`: Object of class "list". Stores the children of each set, indicated by indices.
- `sets`: Object of class "list". Stores the sets that are used for the DAG construction.
- `twoway`: Object of class "logical". Is TRUE if the final DAG structure has twoway logical relationships.
Methods

istwoway (DAGstructure): Indicates whether given DAGstructure has twoway relationships.

Author(s)
Rosa Meijer: <r.j.meijer@lumc.nl>

See Also

DAGmethod

Examples

# Let us assume we have the following sets that we want to test:
ssets <- list(c(1,2,3,4), c(1,2), c(2,3,4), c(2,3), c(1, 2, 3, 4))
# The sets need to have names in order to be able to look up their p-values later
setnames(ssets) <- c(1234, 12, 234, 23, 1, 2, 3, 4)

# Start by making the corresponding graph structure
struct <- construct(ssets)

# Check whether the DAG has twoway logical relations:
istwoway(struct)
Methods

pvalue (hommel.indicator): Retrieves adjusted p-values for all possible hypotheses (as specified by indicator) from the hommel object. If no indicator is given, all adjusted p-values are returned.

Author(s)

Rosa Meijer: <r.j.meijer@lumc.nl>

See Also

pickSimes, curveSimes.

Examples

#Generate a vector of p-values
set.seed(1)
n <- 1000
pvalues <- c(runif(0.50*n,0,0.001), runif(0.50*n,0,1))

#Create an hommel object in which the adjusted p-values are stored, based on a Simes'test
#(or Hommel's test, by choosing simes = FALSE):
hom <- hommelfast(pvalues, simes = TRUE)

#To check how many of the hypotheses within a certain subset have to be false with 95% confidence, the pickSimes function can be used. If no subset is selected, the whole set of hypotheses is used.
pickSimes(hom, alpha=0.05, silent=FALSE)

#The same can be done for any subset, for example the first 10 hypotheses:
pickSimes(hom, select=1:10, alpha=0.05, silent=FALSE)

#A plot can be made that displays the results of pickSimes (i.e. the lower confidence bounds)
#but for selecting only the first 1,2,3,... hypotheses from the selected set.
curveSimes(hom, select=1:10, alpha=0.05, plot=FALSE)
Arguments

pvalues   A vector of p-values.
simes     If TRUE, a Simes' test is used, if FALSE Hommel's test is used.

Value

Returns a `hommel` object.

Author(s)

Rosa Meijer: <r.j.meijer@lumc.nl>

Examples

```r
# Generate a vector of pvalues
set.seed(1)
n <- 1000
pvalues <- c(runif(0.50*n,0,0.001), runif(0.50*n,0,1))

# Create an hommel object in which the adjusted p-values are stored, based on a Simes' test
# (or Hommel's test, by choosing simes = FALSE):
hom <- hommelfast(pvalues, simes = TRUE)

# Retrieve the first 10 adjusted p-values by using the \code{pvalue} method.
pvalue(hom,1:10)
```

Description

P-values for the null hypothesis of no change in the average eighth-grade mathematics achievement scores for the 34 states that participated in both the 1990 and the 1992 National Assessment of Educational Progress (NAEP) Trial State Assessment.

Usage

data(NAEP)

Format

A named numeric vector of p-values, uncorrected for multiple testing.
References


Description

Calculates confidence limits for the number of true hypotheses on the basis of the closed testing procedure.

Usage

pick (closure, reject, alpha, silent=FALSE, plot=FALSE)

Arguments

closure An object of class closure, typically created through a call to closed.

reject A character vector identifying the hypotheses to be rejected. Must be a subvector of hypotheses(closure).

alpha For closure objects with adjusted p-values, specifies the value of alpha for which confidence limits are to be calculated (optional).

silent If FALSE, prints the result to the screen.

plot Whether a confidence distribution should be plotted. Only available for closure objects with adjusted p-values.

Details

The function pick calculates a confidence interval for the number of true hypotheses among a selected set of hypotheses.

Value

The function returns the upper confidence limit for the number of true hypotheses among the set reject. The lower confidence limit is always equal to 0. If closed was called with alpha=NA, a confidence distribution is plotted and returned.

Author(s)

Jelle Goeman: <j.j.goeman@lumc.nl>
Examples

```r
# Example: the birthwt data set from the MASS library
# We want to find variables associated with low birth weight
library(MASS)
fullfit <- glm(low~age+lwt+race+smoke+ptl+ht+ui+ftv, family=binomial, data=birthwt)
hypotheses <- c("age", "lwt", "race", "smoke", "ptl", "ht", "ui", "ftv")

# Define the local test to be used in the closed testing procedure
mytest <- function(hyps) {
  others <- setdiff(hypotheses, hyps)
  form <- formula(paste(c("low-", paste(c("1", others), collapse="+")))))
  anov <- anova(glm(form, data=birthwt, family=binomial), fullfit, test="Chisq")
  res <- anov$Pr("[2]
  if (is.null(res)) res <- anov$P("[2]  # earlier versions
  res
}

# perform the closed testing
cl <- closed(mytest, hypotheses)
summary(cl)

# how many variables among a chosen set are associated with the response?
pick(cl, c("ht", "lwt", "smoke", "ui"))
```

---

Plot region objects

Visualizing of the region hypotheses that could be rejected.

Description

Visualizes region objects as created through a call to `regionmethod`.

Usage

```r
regionplot (region, alpha, color="red")

regionplot2 (region, alpha, color_rej="red", color_unrej="grey")
```

Arguments

- `region` An object of class `region`, typically created through a call to `regionmethod`.
- `alpha` For region objects with adjusted p-values, specifies the value of alpha for which rejections should be plotted (optional).
- `color` Color that is used to indicate rejected region hypotheses.
- `color_rej` Color that is used to indicate rejected region hypotheses.
- `color_unrej` Color that is used to indicate unrejected region hypotheses.
Details

Both plot functions create a graph that visualizes all possible region hypotheses. Each region hypothesis is a node in the graph, and from each region hypothesis two edges connect the hypothesis with its child hypotheses. The `regionplotR` function visualized the graph with its nodes and edges. This function is especially useful for `region` objects with a limited number of elementary hypotheses. The `regionplot` function does not display the nodes and edges separately, but draws a polygon that follows the original graph structure.

Author(s)

Rosa Meijer: <r.j.meijer@lumc.nl>

Examples

```r
# generate data, where the response Y is associated with certain groups of covariates
# namely cov 3-6, 9-12, 15-18
set.seed(1)
n = 100
p = 20
X <- matrix(rnorm(n*p), n, p)
beta <- c(rep(0,2),rep(1,4),rep(0,2),rep(1,4),rep(0,2),rep(1,4),rep(0,2))
Y <- X %*% beta + rnorm(n)

# Define the local test to be used in the closed testing procedure
mytest <- function(left,right) {
  X <- X[, (left:right), drop=FALSE]
  lm.out <- lm(Y ~ X)
  x <- summary(lm.out)
  return(pf(x$fstatistic[1],x$fstatistic[2],x$fstatistic[3],lower.tail=FALSE))
}

# perform the region procedure
reg <- regionmethod(rep(1,p), mytest, isadjusted=TRUE)
summary(reg)

# what are the smallest regions that are found to be significant?
implications(reg)

# how many covariates within the full region of length 20 are at least associated with the response?
regionpick(reg, list(c(1,p)), alpha=0.05)

# visualize the results by either plotting a polygon corresponding to the underlying graph
regionplot(reg)

# or by plotting the graph itself
regionplot2(reg)
```
Region class

Class "region" for storing the result of the region procedure

Description

The class region is the output of a call to regionmethod. It stores which region hypotheses have been rejected and can be used to calculate confidence sets for the number of true and/or false hypotheses among a selected region.

Slots

These slots are not meant to be directly accessed by the user.

weights: Object of class "numeric". Stores the weights of elementary hypotheses.

isadjusted: Object of class "logical". Stores whether adjusted p-values are calculated.

allpvalues: Object of class "matrix". Stores (adjusted) p-values for all possible region hypotheses. Has value NA if adjusted p-value is larger than alpha. Corresponds to a 0x0 matrix if all_pvalues is set to FALSE (by default).

implications: Object of class "matrix". Stores implications including (adjusted) p-values at chosen alpha-level

alpha: Object of class "numeric". The type I error level chosen.

totalrejected: Object of class "numeric". Stores the total number of rejected region hypotheses.

Methods

show (region): Prints how many region hypotheses were tested and how many of them were rejected.

summary (region): Prints the test results (as show).

alpha (region): Retrieves the maximal alpha_value from the region object.

implications (region, alpha): Retrieves the implications from a given region object. By default, the alpha-level is set to alpha_max, but the alpha level can be varied, if the supporting information is present in the region object.

pvalue (region, left, right): Retrieves p-values for all possible region hypotheses (indicated with left and right bound) from the region object. Only able to return the value if the allpvalues matrix is stored in the region object.

Author(s)

Rosa Meijer: <r.j.meijer@lumc.nl>

See Also

regionmethod, regionpick.
Examples

```r
# generate data, where the response Y is associated with certain groups of covariates
# namely cov 3-6, 9-12, 15-18
set.seed(1)
n = 100
p = 20
X <- matrix(rnorm(n*p),n,p)
beta <- c(rep(0.2),rep(1.4),rep(0.2),rep(1.4),rep(0.2),rep(1.4),rep(0.2))
Y <- X %*% beta + rnorm(n)

# Define the local test to be used in the closed testing procedure
mytest <- function(left,right)
{
  X <- X[, (left:right), drop=FALSE]
  lm.out <- lm(Y ~ X)
  x <- summary(lm.out)
  return(pf(x$statistic[1],x$statistic[2],x$statistic[3],lower.tail=FALSE))
}

# perform the region procedure
reg <- regionmethod(rep(1,p), mytest, isadjusted=TRUE, all_pvalues=TRUE)
summary(reg)

# what are the smallest regions that are found to be significant?
implications(reg)

# what are the smallest regions that are found to be significant at an alpha-level of 0.03?
implications(reg, alpha=0.03)

# what is the adjusted p-value of the overall null-hypothesis
# (corresponding to the region ranging from 1 to 20)?
pvalue(reg,1,20)

# how many covariates within the full region of length 20 are at least associated with the response?
regionpick(reg, list(c(1,p)), alpha=0.05)

# visualize the results by either plotting a polygon corresponding to the underlying graph
regionplot(reg)

# or by plotting the graph itself
regionplot2(reg)
```

Description

Tests all possible region hypotheses in a given region while controlling the FWER, using a user-specified local test.
Usage

regionmethod (weights, test, alpha_max = 0.05, all_pvalues = FALSE, isadjusted = FALSE, verbose = FALSE)

Arguments

weights a vector that indicates the weight each elementary hypotheses should receive in the multiple testing procedure. The length of the vector should equal the number of elementary hypotheses. All values should be strictly positive.

test A function that performs the local test. The function should have the left and rightbound of the region as input (as two separate numbers), and return a p-value.

alpha_max The significance level of the test procedure.

all_pvalues If set to TRUE, the procedure will return a matrix with the p-values of all tested region hypotheses. If set to FALSE, only the p-values of the implications will be returned.

isadjusted If set to TRUE, adjusted p-values will be calculated. Otherwise, the p-values of all rejected hypotheses will equal alpha_max.

verbose If set to TRUE, while running the method, a counter will indicate how many region hypotheses are already rejected.

Details

The function regionmethod tests all possible region hypotheses within one main interval, while controlling the familywise error rate.

Value

The function regionmethod returns an object of class region.

Note

The number of region hypotheses is quadratic in the number of elementary hypotheses. The number of elementary hypotheses should for computational reasons not be too large. For values in between 1000 and 10.000 the region procedure can still be used, but one might consider calculating the individual raw p-values beforehand.

If both isadjusted and all_pvalues are set to TRUE, afterwards implications can be obtained for all alpha-values smaller or equal to alpha_max.

Author(s)

Rosa Meijer: <r.j.meijer@lumc.nl>

References

Examples

#generate data, where the response Y is associated with certain groups of covariates
#namely cov 3-6, 9-12, 15-18
set.seed(1)
n=100
p=20
X <- matrix(rnorm(n*p), n, p)
beta <- c(rep(0,2),rep(1,4),rep(0,2),rep(1,4),rep(0,2),rep(1,4),rep(0,2))
Y <- X %*% beta + rnorm(n)

# Define the local test to be used in the closed testing procedure
mytest <- function(left,right)
{
  X <- X[, (left:right), drop=FALSE]
  lm.out <- lm(Y ~ X)
  x <- summary(lm.out)
  return(pf(x$fstatistic[1],x$fstatistic[2],x$fstatistic[3],lower.tail=FALSE))
}

# perform the region procedure
reg <- regionmethod(rep(1,p), mytest, isadjusted=TRUE)
summary(reg)

#what are the smallest regions that are found to be significant?
implications(reg)

#at least how many covariates within the full region of length 20
#are associated with the response?
regionpick(reg, list(c(1,p)), alpha=0.05)

#visualize the results by either plotting a polygon corresponding to the underlying graph
regionplot(reg)

#or by plotting the graph itself
regionplot2(reg)

regionpick

Confidence limits for the number of false hypotheses in a given region.

Description

Calculates confidence limits for the number of false hypotheses on the basis of the region procedure within one or more regions.

Usage

regionpick (region, intervals, alpha, silent = FALSE, ignore_weights = TRUE)
Arguments

- `region`: An object of class `region`, typically created through a call to `regionmethod`.
- `intervals`: A list containing one or more regions, specified by a left and right bound.
- `alpha`: For region objects with adjusted p-values, specifies the value of alpha for which confidence limits are to be calculated (optional).
- `silent`: If FALSE, prints the result to the screen.
- `ignore_weights`: If set to TRUE, a confidence interval for the number of false elementary hypotheses will be computed. If set to FALSE, a confidence interval for the combined weight of false elementary hypotheses will be computed.

Details

The function `regionpick` calculates a confidence interval for the number (or weight) of false hypotheses among a selected set of elementary hypotheses.

Value

The function returns the lower confidence limit for the number of false hypotheses (i.e. true findings) among the set of elementary hypotheses as specified by `intervals`. The upper confidence limit is always equal to the size of the set.

Author(s)

Rosa Meijer: <r.j.meijer@lumc.nl>

Examples

```r
# generate data, where the response Y is associated with certain groups of covariates 
# namely cov 3-6, 9-12, 15-18
set.seed(1)
N = 100
p = 20
X <- matrix(rnorm(n*p), n, p)
beta <- c(rep(0,2), rep(1,4), rep(0,2), rep(1,4), rep(0,2), rep(1,4), rep(0,2))
Y <- X %*% beta + rnorm(n)

# Define the local test to be used in the closed testing procedure
mytest <- function(left,right)
{
  X <- X[, (left:right), drop=FALSE]
  lm.out <- lm(Y ~ X)
  x <- summary(lm.out)
  return(pf(x$fstatistic[1], x$fstatistic[2], x$fstatistic[3], lower.tail=FALSE))
}

# perform the region procedure
reg <- regionmethod(rep(1,p), mytest, isadjusted=TRUE)
summary(reg)
```
Select with shortcuts

Confidence limits for the number of true hypotheses, with shortcuts.

Description

Calculates confidence limits for the number of true hypotheses on the basis of the closed testing procedure using specific local tests that allow shortcuts.

Usage

pickFisher (p, select = seq_along(p), alpha = 0.05, silent = FALSE)

curveFisher (p, select = seq_along(p), order, alpha = 0.05, plot = TRUE)

pickSimes (hommel, select, alpha = 0.05, silent = FALSE)

curveSimes (hommel, select, order, alpha = 0.05, plot = TRUE)

pickMeinshausen (p, PM, select = seq_along(p), alpha = 0.05, silent = FALSE)

curveMeinshausen (p, PM, select = seq_along(p), order, alpha = 0.05, plot = TRUE)

Arguments

- **p**: The vector of p-values for all tested hypotheses.
- **hommel**: The hommel object, obtained from the hommelFast function.
- **PM**: A matrix of permutation p-values. Rows are hypotheses; columns are permutations.
- **select**: The indexing vector of the p-values of the hypotheses to be selected. May be any type of appropriate indexing vector (integers, logical, or character).
- **order**: The indexing vector specifying the order in which p-values of the hypotheses are to be rejected. May be integer or character.
- **alpha**: The significance level of the test procedure.
- **silent**: If FALSE, prints verbose result to the screen.
- **plot**: If TRUE, plots the curve of correct rejections versus total rejections.
Details

The results of the pickFisher, pickSimes and pickMeinshausen functions are identical to applying closed and pick, for specific choices of the local test, but are computationally more efficient. pickFisher uses local tests based on Fisher combinations. This local test is only valid if p-values of true hypotheses are independent. pickSimes uses a local test based on Simes’ inequality. It is valid if p-values of true hypotheses are independent but also under some forms of positive correlations. The Hommel variant of the Simes local test is valid under any dependence structure of the p-values. pickMeinshausen is a permutation-based variant of pickSimes. See the reference below.

In the curve functions, the user may specify either select or order. Specifying order fixes the precise order in which hypotheses are selected, whereas specifying select only specifies which hypotheses are candidates for selection, leaving the order to be chosen by the function to maximize the number of correct rejections.

Value

For pickFisher, pickSimes and pickMeinshausen, the function returns the lower confidence limit for the number of false hypotheses (correct rejection) among the set reject. The upper confidence limit is always equal to the number of rejections made. curveFisher and curveSimes return the same confidence limit, but for selecting only the first 1,2,3,... hypotheses from the selected set.

Author(s)

Jelle Goeman: <j.j.goeman@lumc.nl>; Aldo Solari

References


Examples

```r
# Fisher's method
data(NAEP)
pickFisher(NAEP, c("NH", "NC", "IA"))
pickFisher(NAEP, 1:7)
curveFisher(NAEP)
curveFisher(NAEP, order=7:1)

# Simes method
hom <- hommelfast(NAEP)
pickSimes(hom, c("NH", "NC", "IA"))
pickSimes(hom, 1:7)
curveSimes(hom)
curveSimes(hom, select=1:7)

# Meinshausen's method
library(multtest)
data(golub)
smallglb <- golub[1:500,]
```
structured Holm

Testing of hypotheses, forming a DAG, by using a variant of Holm’s method.

Description

Tests all hypotheses in a given DAG while controlling the FWER, using a user-specified local test.

Usage

structuredHolm(DAGstructure, test, alpha_max = 0.05, isadjusted = FALSE, optimization = "none", pvalues = NULL, verbose = FALSE)

Arguments

DAGstructure DAGstructure object, as returned by the function construct.
test A function that performs the local test. The function should have a set as input and return a p-value.
alpha_max The significance level of the test procedure.
isadjusted If set to TRUE, adjusted p-values will be calculated. Otherwise, the p-values of all rejected hypotheses will equal alpha_max.
optimization Can be, in ascending order of accuracy and computational costs: "none", "LP" (linear programming) or "ILP" (integer linear programming).
pvalues Optional (in case of stored p-values): a vector in which the raw p-values of the exact sets as found in the DAGstructure argument are stored (in the same order). If the test function is provided, this argument is not necessary.
verbose If set to TRUE, while running the method, a counter will indicate how many hypotheses are already rejected.

Details

The function structuredHolm tests all possible hypotheses within a given DAG structure, while controlling the familywise error rate.
Value

The function `structuredHolm` returns an object of class `DAG`.

Author(s)

Rosa Meijer: <r.j.meijer@lumc.nl>

References


See Also

DAG, DAGstructure, construct, DAGpick.

Examples

```r
# Generate data, where the response Y is associated with two (out of 4) covariates
set.seed(1)
n <- 100
p <- 4
X <- matrix(rnorm(n*p), n, p)
beta <- c(0.0, 0.5, 0.5, 0)
Y <- X %*% beta + rnorm(n)

# Let us assume we have the following sets that we want to test:
sets <- list(c(1, 2, 3, 4), c(1, 2), c(2, 3, 4), c(2, 3), 1, 2, 3, 4)
names(sets) <- c(1234, 12, 234, 23, 1, 2, 3, 4)

# Start by making the corresponding graph structure
struct <- construct(sets)

# Check whether the DAG has two-way logical relations:
istwoway(struct)

# Define the local test to be used in the closed testing procedure.
# This test expects a set as input.
mytest <- function(set)
{
  X <- X[, set, drop=FALSE]
  lm.out <- lm(Y ~ X)
  x <- summary(lm.out)
  return(pf(x$fstatistic[1], x$fstatistic[2], x$fstatistic[3], lower.tail=FALSE))
}

# Perform the structuredHolm procedure.
DAG <- structuredHolm(struct, mytest, isadjusted=TRUE)
summary(DAG)

# What are the smallest sets that are found to be significant?
implications(DAG)
```
# What is the adjusted p-value of the null-hypothesis corresponding to the fourth set, # which is set c(2,3)?
# To look up the p-value, the function uses the index or name of the set # in the list of sets stored in the DAGstructure.
# (Note that, if there were duplicate sets in the original list, this index can be different from # the one in the original list given to \code{construct})
pvalue(DAG,4)
pvalue(DAG, "23") # as above, but while using names

# How many of the elementary hypotheses (the last 4 sets) have to be false # with probability 1-alpha?  
# Sets (don't have to be elementary hypotheses in general) must be specified # by their index or name.
DAGpick(DAG, 5:8)
DAGpick(DAG, c("1","2","3","4")) # as above, but while using names
Index

*Topic datasets
  NAEP, 16

*Topic htest
  Adjusted, 2
  Closed Testing, 3
  Pick, 17
  Select with shortcuts, 25

*Topic methods
  Closure class, 5
  DAG class, 7
  DAGstructure class, 13
  hommel class, 14
  Region class, 20

  Adjusted, 2
  adjusted (Adjusted), 2
  alpha (Closure class), 5
  alpha, closure-method (Closure class), 5
  alpha, DAG-method (DAG class), 7
  alpha, region-method (Region class), 20
  alpha<-(Closure class), 5
  alpha<-,-closure-method (Closure class), 5

  closed, 2, 5, 17, 26
  closed (Closed Testing), 3
  Closed Testing, 3
  closure, 2, 4, 17
  closure (Closure class), 5
  Closure class, 5
  closure-class (Closure class), 5
  construct, 10, 13, 28
  construct (Construct the DAG from a given collection of sets.), 6
  Construct the DAG from a given collection of sets., 6
  curveFisher (Select with shortcuts), 25
  curveMeinshausen (Select with shortcuts), 25
  curveSimes, 15

curveSimes (Select with shortcuts), 25
DAG, 10, 12, 28
DAG (DAG class), 7
DAG class, 7
DAG Testing, 9
DAG-class (DAG class), 7
DAGmethod, 7, 8, 12, 14
DAGmethod (DAG Testing), 9
DAGpick, 8, 10, 12, 28
DAGstructure, 6, 7, 10, 28
DAGstructure (DAGstructure class), 13
DAGstructure class, 13
DAGstructure-class (DAGstructure class), 13
defining (Closure class), 5
defining, closure-method (Closure class), 5

hommel, 16
hommel (hommel class), 14
hommel class, 14
hommel-class (hommel class), 14
hommelFast, 14, 15
hypotheses (Closure class), 5
hypotheses, closure-method (Closure class), 5

implications (Region class), 20
implications, DAG-method (DAG class), 7
implications, region-method (Region class), 20
istwoway (DAGstructure class), 13
istwoway, DAGstructure-method (DAGstructure class), 13

NAEP, 16

Pick, 17
pick, 5, 26
pick (Pick), 17
INDEX

pickFisher (Select with shortcuts), 25
pickMeinshausen (Select with shortcuts), 25
pickSimes, 15
pickSimes (Select with shortcuts), 25
Plot region objects, 18
pvalue (Region class), 20
pvalue, DAG-method (DAG class), 7
pvalue, hommel-method (hommel class), 14
pvalue, region-method (Region class), 20

region, 18, 19, 22, 24
region (Region class), 20
Region class, 20
Region Testing, 21
region-class (Region class), 20
regionMethod, 18, 20, 24
regionMethod (Region Testing), 21
regionpick, 20, 23
regionPlot (Plot region objects), 18
regionPlot2 (Plot region objects), 18

Select with shortcuts, 25
shortlist (Closure class), 5
shortlist, closure-method (Closure class), 5
show, closure-method (Closure class), 5
show, DAG-method (DAG class), 7
show, region-method (Region class), 20
structured Holm, 27
structuredHolm, 8
structuredHolm (structured Holm), 27
summary, closure-method (Closure class), 5
summary, DAG-method (DAG class), 7
summary, region-method (Region class), 20