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Author Brian Ripley [aut, cre]
Maintainer Brian Ripley <ripley@stats.ox.ac.uk>
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cv.tree  Cross-validation for Choosing Tree Complexity

Description

Runs a K-fold cross-validation experiment to find the deviance or number of misclassifications as a function of the cost-complexity parameter \( k \).

Usage

cv.tree(object, rand, FUN = prune.tree, K = 10, ...)

Arguments

- **object**: An object of class "tree".
- **rand**: Optionally an integer vector of the length the number of cases used to create `object`, assigning the cases to different groups for cross-validation.
- **FUN**: The function to do the pruning.
- **K**: The number of folds of the cross-validation.
- **...**: Additional arguments to `FUN`.

Value

A copy of `FUN` applied to `object`, with component dev replaced by the cross-validated results from the sum of the dev components of each fit.

Author(s)

B. D. Ripley

See Also

tree, prune.tree

Examples

data(cpus, package="MASS")
cpus.ltr <- tree(log10(perf) ~ syct + mmin + mmax + cach + chmin + chmax, data=cpus)
cv.tree(cpus.ltr, , prune.tree)
deviance.tree

 Extract Deviance from a Tree Object

Description

Extract deviance from a tree object.

Usage

## S3 method for class 'tree'
deviance(object, detail = FALSE, ...)

Arguments

object an object of calls "tree"
detail logical. If true, returns a vector of deviance contributions from each node.

Value

The overall deviance, or a vector of contributions from the cases at each node. The overall deviance is the sum over leaves in the latter case.

misclass.tree

 Misclassifications by a Classification Tree

Description

Report the number of mis-classifications made by a classification tree, either overall or at each node.

Usage

misclass.tree(tree, detail = FALSE)

Arguments

tree Object of class "tree", representing a classification tree.
detail If false, report overall number of mis-classifications. If true, report the number at each node.

Details

The quantities returned are weighted by the observational weights if these are supplied in the construction of tree.
Value

Either the overall number of misclassifications or the number for each node.

Author(s)

B. D. Ripley

See Also

tree

Examples

ir.tr <- tree(Species ~ ., iris)
misclass.tree(ir.tr)
misclass.tree(ir.tr, detail=TRUE)

na.tree.replace

Replace NAs in Predictor Variables

Description

Adds a new level called "NA" to any discrete predictor in a data frame that contains NAs. Stops if any continuous predictor contains an NA.

Usage

na.tree.replace(frame)

Arguments

frame data frame used to grow a tree.

Details

This function is used via the na.action argument to tree.

Value

data frame such that a new level named "NA" is added to any discrete predictor in frame with NAs.

See Also

tree, na.omit.
### partition.tree

**Plot the Partitions of a simple Tree Model**

**Description**

Plot the partitions of a tree involving one or two variables.

**Usage**

```r
partition.tree(tree, label = "yval", add = FALSE, ordvars, ...)
```

**Arguments**

- `tree`: A object of class "tree".
- `label`: A character string giving the column of the frame component of `tree` to be used to label the regions.
- `add`: If true, add to existing plot, otherwise start a new plot.
- `ordvars`: The ordering of the variables to be used in a 2D plot. Specify the names in a character string of length 2; the first will be used on the x axis.
- `...`: Graphical parameters.

**Details**

This can be used with a regression or classification tree containing one or two continuous predictors (only).

If the tree contains one predictor, the predicted value (a regression tree) or the probability of the first class (a classification tree) is plotted against the predictor over its range in the training set.

If the tree contains two predictors, a plot is made of the space covered by those two predictors and the partition made by the tree is superimposed.

**Value**

None.

**Author(s)**

B. D. Ripley

**See Also**

`tree`
Examples

```
ir.tr <- tree(Species ~ ., iris)
ir.tr
ir.tr1 <- snip.tree(ir.tr, nodes = c(12, 7))
summary(ir.tr1)
par(pty = "s")
plot(iris[, 3], iris[, 4], type="n",
     xlab="petal length", ylab="petal width")
text(iris[, 3], iris[, 4], c("s", "c", "v")[[iris[, 5]]])
partition.tree(ir.tr1, add = TRUE, cex = 1.5)
```

# 1D example
```
ir.tr <- tree(Petal.Width ~ Petal.Length, iris)
plot(iris[,3], iris[,4], type="n", xlab="Length", ylab="Width")
partition.tree(ir.tr, add = TRUE, cex = 1.5)
```

---

**plot.tree**

*Plot a Tree Object*

**Description**

Plot a tree object on the current graphical device

**Usage**

```r
## S3 method for class 'tree'
plot(x, y = NULL, type = c("proportional", "uniform"), ...)  
```

**Arguments**

- `x` an object of class "tree".
- `y` ignored. Used for positional matching of type.
- `type` character string. If this partially matches "uniform", the branches are of uniform length. Otherwise they are proportional to the decrease in impurity.
- `...` graphical parameters.

**Value**

An (invisible) list with components `x` and `y` giving the coordinates of the tree nodes.

As a side effect, the value of `type == "uniform"` is stored in the variable `.Tree.unif.?` in the global environment, where `?` is the device number.

**Author(s)**

B. D. Ripley

**See Also**

tree
plot.tree.sequence  

Plot a Tree Sequence

Description

Allows the user to plot a tree sequence.

Usage

```r
## S3 method for class 'tree.sequence'
plot(x, ..., type = "l", ylim = range(x$dev),
     order = c("increasing", "decreasing"))
```

Arguments

- `x` object of class `tree.sequence`. This is assumed to be the result of some function that produces an object with the same named components (size, deviance, k) as that returned by `prune.tree`.
- `order` of size on the plot. Use "decreasing" for the natural ordering of k and the amount of pruning. Only the first character is needed.
- `type`, `ylim`, ... graphical parameters.

Details

This function is a method for the generic function `plot()` for class `tree.sequence`. It can be invoked by calling `plot(x)` for an object x of the appropriate class, or directly by calling `plot.tree.sequence(x)` regardless of the class of the object.

Side Effects

Plots deviance or number of misclassifications (or total loss) versus size for a sequence of trees.

Examples

```r
data(cpus, package="MASS")
cpus.ltr <- tree(log(perf) ~ syct + mmin + mmax + cach + chmin + chmax,
                  data = cpus)
plot(prune.tree(cpus.ltr))
```
predict.tree

Predictions from a Fitted Tree Object

Description

Returns a vector of predicted responses from a fitted tree object.

Usage

```r
## S3 method for class 'tree'
predict(object, newdata = list(),
    type = c("vector", "tree", "class", "where"),
    split = FALSE, nwts, eps = 1e-3, ...)
```

Arguments

- `object`: fitted model object of class tree. This is assumed to be the result of some function that produces an object with the same named components as that returned by the tree function.
- `newdata`: data frame containing the values at which predictions are required. The predictors referred to in the right side of `formula(object)` must be present by name in `newdata`. If missing, fitted values are returned.
- `type`: character string denoting whether the predictions are returned as a vector (default) or as a tree object.
- `split`: governs the handling of missing values. If false, cases with missing values are dropped down the tree until a leaf is reached or a node for which the attribute is missing, and that node is used for prediction. If `split = TRUE` cases with missing attributes are split into fractional cases and dropped down each side of the split. The predicted values are averaged over the fractions to give the prediction.
- `nwts`: weights for the `newdata` cases, used when predicting a tree.
- `eps`: a lower bound for the probabilities, used if events of predicted probability zero occur in `newdata` when predicting a tree.
- `...`: further arguments passed to or from other methods.

Details

This function is a method for the generic function `predict()` for class tree. It can be invoked by calling `predict(x)` for an object `x` of the appropriate class, or directly by calling `predict.tree(x)` regardless of the class of the object.

Value

If `type = "vector"`: vector of predicted responses or, if the response is a factor, matrix of predicted class probabilities. This new object is obtained by dropping `newdata` down `object`. For factor predictors, if an observation contains a level not used to grow the tree, it is left at the deepest possible node and `frame$yval` or `frame$yprob` at that node is the prediction.
If `type = "tree"`: an object of class "tree" is returned with new values for `frame$n` and `frame$dev`. If `newdata` does not contain a column for the response in the formula the value of `frame$dev` will be `NA`, and if some values in the response are missing, the some of the deviances will be `NA`.

If `type = "class"`: for a classification tree, a factor of the predicted classes (that with highest posterior probability, with ties split randomly).

If `type = "where"`: the nodes the cases reach.

References


See Also

`predict.tree`

Examples

```r
data(shuttle, package="MASS")
shuttle.tr <- tree(use ~ ., shuttle, subset=1:253,
               mindev=1e-6, msize=2)
shuttle.tr
shuttle1 <- shuttle[254:256, ] # 3 missing cases
predict(shuttle.tr, shuttle1)
```

---

**prune.tree**  
*Cost-complexity Pruning of Tree Object*

### Description

Determines a nested sequence of subtrees of the supplied tree by recursively "snipping" off the least important splits.

### Usage

```r
prune.tree(tree, k = NULL, best = NULL, newdata, nwts,
           method = c("deviance", "misclass"), loss, eps = 1e-3)

prune.misclass(tree, k = NULL, best = NULL, newdata,
               nwts, loss, eps = 1e-3)
```

### Arguments

- `tree`  
  fitted model object of class `tree`. This is assumed to be the result of some function that produces an object with the same named components as that returned by the `tree()` function.
prune.tree

**k**
cost-complexity parameter defining either a specific subtree of tree (k a scalar) or the (optional) sequence of subtrees minimizing the cost-complexity measure (k a vector). If missing, k is determined algorithmically.

**best**
integer requesting the size (i.e. number of terminal nodes) of a specific subtree in the cost-complexity sequence to be returned. This is an alternative way to select a subtree than by supplying a scalar cost-complexity parameter k. If there is no tree in the sequence of the requested size, the next largest is returned.

**newdata**
data frame upon which the sequence of cost-complexity subtrees is evaluated. If missing, the data used to grow the tree are used.

**nwts**
weights for the newdata cases.

**method**
character string denoting the measure of node heterogeneity used to guide cost-complexity pruning. For regression trees, only the default, deviance, is accepted. For classification trees, the default is deviance and the alternative is misclass (number of misclassifications or total loss).

**loss**
a matrix giving for each true class (row) the numeric loss of predicting the class (column). The classes should be in the order of the levels of the response. It is conventional for a loss matrix to have a zero diagonal. The default is 0–1 loss.

**eps**
a lower bound for the probabilities, used to compute deviances if events of predicted probability zero occur in newdata.

**Details**
Determines a nested sequence of subtrees of the supplied tree by recursively "snipping" off the least important splits, based upon the cost-complexity measure. prune.misclass is an abbreviation for prune.tree(method = "misclass") for use with cv.tree.

If k is supplied, the optimal subtree for that value is returned.

The response as well as the predictors referred to in the right side of the formula in tree must be present by name in newdata. These data are dropped down each tree in the cost-complexity sequence and deviances or losses calculated by comparing the supplied response to the prediction. The function cv.tree() routinely uses the newdata argument in cross-validating the pruning procedure. A plot method exists for objects of this class. It displays the value of the deviance, the number of misclassifications or the total loss for each subtree in the cost-complexity sequence. An additional axis displays the values of the cost-complexity parameter at each subtree.

**Value**
If k is supplied and is a scalar, a tree object is returned that minimizes the cost-complexity measure for that k. If best is supplied, a tree object of size best is returned. Otherwise, an object of class tree.sequence is returned. The object contains the following components:

**size**
number of terminal nodes in each tree in the cost-complexity pruning sequence.

**deviance**
total deviance of each tree in the cost-complexity pruning sequence.

**k**
the value of the cost-complexity pruning parameter of each tree in the sequence.
Examples

data(fgl, package="MASS")
fgl.tr <- tree(type ~ ., fgl)
print(fgl.tr); plot(fgl.tr)

fgl.cv <- cv.tree(fgl.tr,, prune.tree)
for(i in 2:5) fgl.cv$dev <- fgl.cv$dev +
  cv.tree(fgl.tr,, prune.tree)$dev
fgl.cv$dev <- fgl.cv$dev/5
plot(fgl.cv)

---

snip.tree

Snip Parts of Tree Objects

Description

snip.tree has two related functions. If nodes is supplied, it removes those nodes and all their
descendants from the tree.

If nodes is not supplied, the user is invited to select nodes interactively; this makes sense only if the
tree has already been plotted. A node is selected by clicking with the left mouse button; its number
and the deviance of the current tree and that which would remain if that node were removed are
printed. Selecting the same node again causes it to be removed (and the lines of its sub-tree erased).
Clicking any other button terminates the selection process.

Usage

snip.tree(tree, nodes, xy.save = FALSE,
  digits = getOption("digits") - 3)

Arguments

  tree          An object of class "tree".
  nodes         An integer vector giving those nodes that are the roots of sub-trees to be snipped
                off. If missing, the user is invited to select a node at which to snip.
  xy.save       If true, the x and y coordinates selected interactively are saved as attribute .xy
                of the returned value.
  digits        Precision used in printing statistics for selected nodes.

Value

  A tree object containing the nodes that remain after specified or selected subtrees have been snipped
  off.

Note

  Prior to version 1.0-34, the saved coordinates were place in object .xy in the workspace.
text.tree

Annotate a Tree Plot

Description
Add text to a tree plot.

Usage
## S3 method for class 'tree'
text(x, splits = TRUE, label = "yval", all = FALSE,
    pretty = NULL, digits =getOption("digits") - 3,
    adj = par("adj"), xpd = TRUE, ...)

Arguments
x an object of class "tree"
splits logical. If TRUE the splits are labelled
label The name of column in the frame component of x, to be used to label the nodes.
    Can be NULL to suppress node-labelling
all logical. By default, only the leaves are labelled, but if true interior nodes are
    also labelled.
pretty the manipulation used for split labels involving attributes. See Details.
digits significant digits for numerical labels.
adj, xpd, ... graphical parameters such as cex and font.

Details
If pretty = 0 then the level names of a factor split attributes are used unchanged. If pretty = NULL,
the levels are presented by a, b, ... z, 0 ... 5. If pretty is a positive integer, abbreviate is applied
to the labels with that value for its argument minlength.

If the lettering is vertical (par srt = 90) and adj is not supplied it is adjusted appropriately.

Value
None.
tile.tree

Author(s)

B. D. Ripley

See Also

plot.tree

Examples

ir.tr <- tree(Species ~., iris)
plot(ir.tr)
text(ir.tr)

tile.tree

Add Class Barcharts to a Classification Tree Plot

Description

This computes the frequencies of level of var for cases reaching each leaf of the tree, and plots barcharts of the set of frequencies underneath each leaf.

Usage

tile.tree(tree, var, screen.arg = ascr + 1, axes = TRUE)

Arguments

tree

tted object of class "tree".

var

a factor variable to be displayed: by default it is the response factor of the tree.

screen.arg

The screen to be used: default the next after the currently active screen.

axes

logical flag for drawing of axes for the barcharts.

Value

A matrix of counts of categories (rows) for each leaf (columns). The principal effect is the plot.

Author(s)

B. D. Ripley

See Also

tree.screens
Examples

```r
data(fgl, package="MASS")
fgl.tr <- tree(type ~ ., fgl)
summary(fgl.tr)
plot(fgl.tr); text(fgl.tr, all=TRUE, cex=0.5)
fgl.tr1 <- snip.tree(fgl.tr, node=c(108, 31, 26))
tree.screens()
plot(fgl.tr1)
text(fgl.tr1)
tile.tree(fgl.tr1, fgl$type)
close.screen(all = TRUE)
```

**tree**

*Fit a Classification or Regression Tree*

**Description**

A tree is grown by binary recursive partitioning using the response in the specified formula and choosing splits from the terms of the right-hand-side.

**Usage**

```r
tree(formula, data, weights, subset,
     na.action = na.pass, control = tree.control(nobs, ...),
     method = "recursive.partition",
     split = c("deviance", "gini"),
     model = FALSE, x = FALSE, y = TRUE, wts = TRUE, ...)
```

**Arguments**

- `formula`: A formula expression. The left-hand-side (response) should be either a numerical vector when a regression tree will be fitted or a factor, when a classification tree is produced. The right-hand-side should be a series of numeric or factor variables separated by `+`; there should be no interaction terms. Both `.` and `-` are allowed: regression trees can have `offset` terms.
- `data`: A data frame in which to preferentially interpret `formula`, `weights` and `subset`.
- `weights`: Vector of non-negative observational weights; fractional weights are allowed.
- `subset`: An expression specifying the subset of cases to be used.
- `na.action`: A function to filter missing data from the model frame. The default is `na.pass` (to do nothing) as tree handles missing values (by dropping them down the tree as far as possible).
- `control`: A list as returned by `tree.control`.
- `method`: Character string giving the method to use. The only other useful value is "model.frame".
- `split`: Splitting criterion to use.
model If this argument is itself a model frame, then the formula and data arguments are ignored, and model is used to define the model. If the argument is logical and true, the model frame is stored as component model in the result.
x logical. If true, the matrix of variables for each case is returned.
y logical. If true, the response variable is returned.
wts logical. If true, the weights are returned.
... Additional arguments that are passed to tree.control. Normally used for mincut, minsize or mindev.

Details

A tree is grown by binary recursive partitioning using the response in the specified formula and choosing splits from the terms of the right-hand-side. Numeric variables are divided into $X < a$ and $X > a$; the levels of an unordered factor are divided into two non-empty groups. The split which maximizes the reduction in impurity is chosen, the data set split and the process repeated. Splitting continues until the terminal nodes are too small or too few to be split.

Tree growth is limited to a depth of 31 by the use of integers to label nodes.

Factor predictor variables can have up to 32 levels. This limit is imposed for ease of labelling, but since their use in a classification tree with three or more levels in a response involves a search over $2^{(k-1)} - 1$ groupings for $k$ levels, the practical limit is much less.

Value

The value is an object of class "tree" which has components

frame A data frame with a row for each node, and row.names giving the node numbers. The columns include var, the variable used at the split (or "<leaf>" for a terminal node), n, the (weighted) number of cases reaching that node, dev the deviance of the node, yval, the fitted value at the node (the mean for regression trees, a majority class for classification trees) and split, a two-column matrix of the labels for the left and right splits at the node. Classification trees also have yprob, a matrix of fitted probabilities for each response level.

where An integer vector giving the row number of the frame detailing the node to which each case is assigned.
terms The terms of the formula.
call The matched call to Tree.
model If model = TRUE, the model frame.
x If x = TRUE, the model matrix.
y If y = TRUE, the response.
wts If wts = TRUE, the weights.

and attributes xlevels and, for classification trees, ylevels.

A tree with no splits is of class "singlenode" which inherits from class "tree".
Author(s)
B. D. Ripley

References

See Also
tree.control, prune.tree, predict.tree, snip.tree

Examples
```r
data(cpus, package="MASS")
cpus.ltr <- tree(log10(perf) ~ syct+mmin+mmax+cach+chmin+chmax, cpus)
cpus.ltr
summary(cpus.ltr)
plot(cpus.ltr); text(cpus.ltr)

ir.tr <- tree(Species ~., iris)
ir.tr
summary(ir.tr)
```

Description
A utility function for use with the control argument of tree.

Usage
tree.control(nobs, mincut = 5, minsize = 10, mindev = 0.01)

Arguments
- **nobs**: The number of observations in the training set.
- **mincut**: The minimum number of observations to include in either child node. This is a weighted quantity; the observational weights are used to compute the 'number'. The default is 5.
- **minsize**: The smallest allowed node size: a weighted quantity. The default is 10.
- **mindev**: The within-node deviance must be at least this times that of the root node for the node to be split.
Details

This function produces default values of mincut and minsize, and ensures that mincut is at most half minsize.

To produce a tree that fits the data perfectly, set mindev = 0 and minsize = 2, if the limit on tree depth allows such a tree.

Value

A list:

- `mincut`: The maximum of the input or default mincut and 1
- `minsize`: The maximum of the input or default minsize and 2.
- `nmax`: A estimate of the maximum number of nodes that might be grown.
- `nobs`: The input nobs.

Note

The interpretation of mindev given here is that of Chambers and Hastie (1992, p. 415), and apparently not what is actually implemented in S. It seems S uses an absolute bound.

Author(s)

B. D. Ripley

References


See Also

tree

tree.screens

**tree.screens**

**Split Screen for Plotting Trees**

Description

Splits the screen in a way suitable for using tile.tree.

Usage

```
tree.screens(figs, screen.arg = 0, ...)
```
Arguments

figs A specification of the split of the screen. See `split.screen` for the allowed forms.

screen.arg the screen to divide, by default the whole display area.

... plot parameters to be passed to `par`.

Value

A vector of screen numbers for the newly-created screens.

Author(s)

B. D. Ripley

See Also

tile.tree, split.screen

Examples

data(fgl, package="MASS")
fgl.tr <- tree(type ~ ., fgl)
summary(fgl.tr)
plot(fgl.tr); text(fgl.tr, all=TRUE, cex=0.5)
fgl.tr1 <- snip.tree(fgl.tr, node=c(108, 31, 26))
tree.screens()
plot(fgl.tr1)
tile.tree(fgl.tr1, fgl$type)
close.screen(all = TRUE)
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