Package ‘A3’

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Description Supplies tools for tabulating and analyzing the results of predictive models. The methods employed are applicable to virtually any predictive model and make comparisons between different methodologies straightforward.
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Description

A package for the generation of accurate, accessible, and adaptable error metrics for developing high quality predictions and inferences. The name A3 (pronounced "A-Cubed") comes from the combination of the first letters of these three primary adjectives.

Details

The overarching purpose of the outputs and tools in this package are to make the accurate assessment of model errors more accessible to a wider audience. Furthermore, a standardized set of reporting features are provided by this package which create consistent outputs for virtually any predictive model. This makes it straightforward to compare, for instance, a linear regression model to more exotic techniques such as Random forests or Support vector machines.

The standard outputs for each model fit provided by the A3 package include:

- Average Slope: Equivalent to a linear regression coefficient.
- Cross Validated $R^2$: Robust calculation of $R^2$ (percent of squared error explained by the model compared to the null model) values adjusting for over-fitting.
- p Values: Robust calculation of p-values requiring no parametric assumptions other than independence between observations (which may be violated if compensated for).

The primary functions that will be used are a3 for arbitrary modeling functions and a3.lm for linear models. This package also includes print.A3 and plot.A3 for outputting the A3 results.

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Usage

a3(formula, data, model.fn, model.args = list(), ...)

Description

This function calculates the A3 results for an arbitrary model construction algorithm (e.g. Linear Regressions, Support Vector Machines or Random Forests). For linear regression models, you may use the a3.lm convenience function.
Arguments

- **formula**: the regression formula.
- **data**: a data frame containing the data to be used in the model fit.
- **model.fn**: the function to be used to build the model.
- **model.args**: a list of arguments passed to **model.fn**.
- **...**: additional arguments passed to **a3.base**.

Value

S3 A3 object; see **a3.base** for details

References


Examples

```r
## Standard linear regression results:
summary(lm(rating ~ ., attitude))

## A3 Results for a Linear Regression model:
# In practice, p.acc should be <= 0.01 in order
# to obtain finer grained p values.
a3(rating ~ ., attitude, lm, p.acc = 0.1)

## A3 Results for a Random Forest model:
# It is important to include the "+0" in the formula
# to eliminate the constant term.
require(randomForest)
a3(rating ~ .+0, attitude, randomForest, p.acc = 0.1)

# Set the ntree argument of the randomForest function to 100
a3(rating ~ .+0, attitude, randomForest, p.acc = 0.1, model.args = list(ntree = 100))

# Speed up the calculation by doing 5-fold cross-validation.
# This is faster and more conservative (i.e. it should over-estimate error)
a3(rating ~ .+0, attitude, randomForest, n.folds = 5, p.acc = 0.1)

# Use Leave One Out Cross Validation. The least biased approach,
# but, for large data sets, potentially very slow.
```

a3(rating ~ .+0, attitude, randomForest, n.folds = 0, p.acc = 0.1)

## Use a Support Vector Machine algorithm.

# Just calculate the slopes and R^2 values, do not calculate p values.

require(e1071)
a3(rating ~ .+0, attitude, svm, p.acc = NULL)

---

### a3.base

#### Base A3 Results Calculation

**Description**

This function calculates the A3 results. Generally this function is not called directly. It is simpler to use `a3` (for arbitrary models) or `a3.lm` (specifically for linear regressions).

**Usage**

```r
a3.base(formula, data, model.fn, simulate.fn, n.folds = 10,
data.generating.fn = replicate(ncol(x), a3.gen.default), p.acc = 0.01,
features = TRUE, slope.sample = NULL, slope.displacement = 1)
```

**Arguments**

- **formula**: the regression formula.
- **data**: a data frame containing the data to be used in the model fit.
- **model.fn**: function used to generate a model.
- **simulate.fn**: function used to create the model and generate predictions.
- **n.folds**: the number of folds used for cross-validation. Set to 0 to use Leave One Out Cross Validation.
- **data.generating.fn**: the function used to generate stochastic noise for calculation of exact p values.
- **p.acc**: the desired accuracy for the calculation of exact p values. The entire calculation process will be repeated $1/p.acc$ times so this can have a dramatic affect on time required. Set to NULL to disable the calculation of p values.
- **features**: whether to calculate the average slopes, added $R^2$ and p values for each of the features in addition to the overall model.
- **slope.sample**: if not NULL the sample size for use to calculate the average slopes (useful for very large data sets).
- **slope.displacement**: the amount of displacement to take in calculating the slopes. May be a single number in which case the same slope is applied to all features. May also be a named vector where there is a name for each feature.
Value

S3 A3 object containing:

- **model.R2**: The cross validated $R^2$ for the entire model.
- **feature.R2**: The cross validated $R^2$'s for the features (if calculated).
- **model.p**: The p value for the entire model (if calculated).
- **feature.p**: The p value for the features (if calculated).
- **all.R2**: The $R^2$'s for the model features, and any stochastic simulations for calculating exact p values.
- **observed**: The observed response for each observation.
- **predicted**: The predicted response for each observation.
- **slopes**: Average slopes for each of the features (if calculated).
- **all.slopes**: Slopes for each of the observations for each of the features (if calculated).
- **table**: The A3 results table.

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**Stochastic Data Generators**

**Description**

The stochastic data generators generate stochastic noise with (if specified correctly) the same properties as the observed data. By replicating the stochastic properties of the original data, we are able to obtain the exact calculation of p values.

**Usage**

```r
a3.gen.default(x, n.reps)
```

**Arguments**

- `x`: the original (observed) data series.
- `n.reps`: the number of stochastic repetitions to generate.

**Details**

Generally these will not be called directly but will instead be passed to the `data.generating.fn` argument of `a3.base`. 
Value

A list of of length n.reps of vectors of stochastic noise. There are a number of different methods of generating noise:

- `a3.gen.default` The default data generator. Uses `a3.gen.bootstrap`.
- `a3.gen.resample` Resorders the original data series.
- `a3.gen.bootstrap` Resamples the original data series with replacement.
- `a3.gen.normal` Calculates the mean and standard deviation of the original series and generates a new series with that distribution.
- `a3.gen.autocor` Assumes a first order autocorrelation of the original series and generates a new series with the same properties.

Examples

```r
# Calculate the A3 results assuming an auto-correlated set of observations.
# In usage p.acc should be <=0.01 in order to obtain more accurate p values.

a3.lm(rating ~ ., attitude, p.acc = 0.1,
       data.generating.fn = replicate(ncol(attitude), a3.gen.autocor))

## A general illustration:
# Take x as a sample set of observations for a feature
x <- c(0.349, 1.845, 2.287, 1.921, 0.803, 0.855, 2.368, 3.023, 2.102, 4.648)

# Generate three stochastic data series with the same autocorrelation properties as x
rand.x <- a3.gen.autocor(x, 3)

plot(x, type="l")
for(i in 1:3) lines(rand.x[[i]], lwd = 0.2)
```

a3.lm

A3 for Linear Regressions

Description

This convenience function calculates the A3 results specifically for linear regressions. It uses R’s `glm` function and so supports logistic regressions and other link functions using the `family` argument. For other forms of models you may use the more general `a3` function.

Usage

```
a3.lm(formula, data, family = gaussian, ...)
```
Arguments

- **formula**: the regression formula.
- **data**: a data frame containing the data to be used in the model fit.
- **family**: the regression family. Typically 'gaussian' for linear regressions.
- **...**: additional arguments passed to `a3.base`.

Value

S3 A3 object; see `a3.base` for details

Examples

```r
## Standard linear regression results:
summary(lm(rating ~ ., attitude))
## A3 linear regression results:
# In practice, p.acc should be <= 0.01 in order
# to obtain fine grained p values.
a3.lm(rating ~ ., attitude, p.acc = 0.1)
# This is equivalent both to:
a3(rating ~ ., attitude, glm, model.args = list(family = gaussian), p.acc = 0.1)
# and also to:
a3(rating ~ ., attitude, lm, p.acc = 0.1)
```

---

a3.r2  

Cross-Validated $R^2$

Description

Applies cross validation to obtain the cross-validated $R^2$ for a model: the fraction of the squared error explained by the model compared to the null model (which is defined as the average response). A pseudo $R^2$ is implemented for classification.

Usage

```r
a3.r2(y, x, simulate.fn, cv.folds)
```
Arguments

\( y \)  
- a vector or responses.
\( x \)  
- a matrix of features.
\( \text{simulate.fn} \)  
- a function object that creates a model and predicts \( y \).
\( \text{cv.folds} \)  
- the cross-validation folds.

Value

A list comprising of the following elements:

- \( \text{R2} \)  
  - the cross-validated \( R^2 \)
- \( \text{predicted} \)  
  - the predicted responses
- \( \text{observed} \)  
  - the observed responses

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**housing**  
**Boston Housing Prices**

Description

A dataset containing the prices of houses in the Boston region and a number of features. The dataset and the following description is based on that provided by UCI Machine Learning Repository (http://archive.ics.uci.edu/ml/datasets/Housing).

Usage

```
data(housing)
```

Details

- CRIME: Per capita crime rate by town
- ZN: Proportion of residential land zoned for lots over 25,000 sq.ft.
- INDUS: Proportion of non-retail business acres per town
- CHAS: Charles River dummy variable (= 1 if tract bounds river; 0 otherwise)
- NOX: Nitrogen oxides pollutant concentration (parts per 10 million)
- ROOMS: Average number of rooms per dwelling
- AGE: Proportion of owner-occupied units built prior to 1940
- DISTANCE: Weighted distances to five Boston employment centres
- HIGHWAY: Index of accessibility to radial highways
- TAX: Full-value property-tax rate per ten thousand dollar
- PUPIL.TEACHER: Pupil-teacher ratio by town
- MINORITY: 1000(Bk - 0.63)^2 where Bk is the proportion of blacks by town
- LSTAT: Percent lower status of the population
- MED.VALUE: Median value of owner-occupied homes in thousands of dollars
multifunctionality

References


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multifunctionality  Ecosystem Multifunctionality

Description

This dataset relates multifunctionality to a number of different biotic and abiotic features in a global survey of drylands. The dataset was obtained from (http://www.sciencemag.org/content/335/6065/214/suppl/DC1). The dataset contains the features listed below.

Usage

```
data(multifunctionality)
```

Details

- ELE: Elevation of the site
- LAT & LONG: Location of the site
- SLO: Site slope
- SAC: Soil sand content
- PCA_C1, PCA_C2, PCA_C3, PCA_C4: Principal components of a set of 21 climatic features
- SR: Species richness
- MUL: Multifunctionality

References

plotPredictions

plot.A3  Plot A3 Results

Description
Plots an 'A3' object results. Displays predicted versus observed values for each observation along with the distribution of slopes measured for each feature.

Usage
## S3 method for class 'A3'
plot(x, ...)

Arguments
x
an A3 object.
...
additional options provided to plotPredictions, plotSlopes and plot functions.

Examples

data(housing)
res <- a3.lm(MED.VALUE ~ NOX + ROOMS + AGE + HIGHWAY + PUPIL.TEACHER, housing, p.acc = NULL)
plot(res)

plotPredictions  Plot Predicted versus Observed

Description
Plots an 'A3' object's values showing the predicted versus observed values for each observation.

Usage
plotPredictions(x, show.equality = TRUE, xlab = "Observed Value",
ylab = "Predicted Value", main = "Predicted vs Observed", ...)

Arguments
x
an A3 object,
show.equality
if true plot a line at 45-degrees.
xlab
the x-axis label.
ylab
the y-axis label.
main
the plot title.
...
additional options provided to the plot function.
plotSlopes

Examples

```r
data(multifunctionality)
x <- a3.lm(MUL ~ ., multifunctionality, p.acc = NULL, features = FALSE)
plotPredictions(x)

# plotSlopes
Plot Distribution of Slopes

Description
Plots an 'A3' object's distribution of slopes for each feature and observation. Uses Kernel Density Estimation to create an estimate of the distribution of slopes for a feature.

Usage
plotSlopes(x, ...)

Arguments

x
an A3 object.

...
additional options provided to the plot and density functions.

Examples

```r
require(randomForest)
data(housing)
x <- a3(MED.VALUE ~ NOX + PUPIL.TEACHER + ROOMS + AGE + HIGHWAY + 0, housing, randomForest, p.acc = NULL, n.folds = 2)
plotSlopes(x)
```

print.A3

Print Fit Results

Description
Prints an 'A3' object results table.

Usage

```r
## S3 method for class 'A3'
print(x, ...)
```
Arguments

x an A3 object.
...
additional arguments passed to the print function.

Examples

x <- a3.lm(rating ~ ., attitude, p.acc = NULL)
print(x)

xtable.A3 Nicely Formatted Fit Results

Description

Creates a LaTeX table of results. Depends on the xtable package.

Usage

## S3 method for class 'A3'
xtable(x, ...)

Arguments

x an A3 object.
...
additional arguments passed to the print.xtable function.

Examples

x <- a3.lm(rating ~ ., attitude, p.acc = NULL)
xtable(x)
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