NAG Library Function Document

nag_simple_linear_regression (g02cac)

1 Purpose

nag_simple_linear_regression (g02cac) performs a simple linear regression with or without a constant term. The data is optionally weighted.

2 Specification

```
#include <nag.h>
#include <nagg02.h>
void nag_simple_linear_regression (Nag_SumSquare mean, Integer n,
     const double x[], const double y[], const double wt[], double *a,
     double *b, double *a_serr, double *b_serr, double *rsq, double *rss,
     double *df, NagError *fail)
```

3 Description

nag_simple_linear_regression (g02cac) fits a straight line model of the form,

$$E(y) = a + bx,$$

where $E(y)$ is the expected value of the variable y, to the data points

$$(x_1, y_1), (x_2, y_2), \ldots, (x_n, y_n),$$

such that

$$y_i = a + bx_i + e_i, i = 1, 2, \ldots, n(n > 2).$$

where the e_i values are independent random errors. The ith data point may have an associated weight w_i, these may be used either in the situation when var $(\epsilon_i) = \sigma^2/w_i$ or if observations have to be removed from the regression by having zero weight or have been observed with frequency w_i.

The regression coefficient, b, and the regression constant, a are estimated by minimizing

$$\sum_{i=1}^{n} w_i e_i^2,$$

if the weights option is not selected then $w_i = 1.0$.

The following statistics are computed:

the estimate of regression constant $\hat{a} = \bar{y} - \hat{b}\bar{x}$,

the estimate of regression coefficient $\hat{b} = \frac{\sum w_i(x_i - \bar{x})(y_i - \bar{y})}{\sum w_i(x_i - \bar{x})^2}$,

the residual sum of squares $rss = \sum w_i(y_i - \hat{y}_i)^2$,

where the weighted means $\bar{x}$ and $\bar{y}$ are

$$\bar{x} = \frac{\sum w_i x_i}{\sum w_i} \quad \text{and} \quad \bar{y} = \frac{\sum w_i y_i}{\sum w_i}.$$

The number of degrees of freedom associated with rss is

$df = \sum w_i - 2$ where **mean** = Nag_AboutMean

$df = \sum w_i - 1$ where **mean** = Nag_AboutZero

Note: the weights should be scaled to give the correct degrees of freedom in the case var $(\epsilon_i) = \sigma^2/w_i$.

The R^2 value or coefficient of determination

$$R^2 = \frac{\sum w_i(\hat{y}_i - \bar{y}_i)^2}{\sum w_i(y_i - \bar{y})^2} = \frac{\sum w_i(y_i - \bar{y})^2 - rss}{\sum w_i(y_i - \bar{y})^2}.$$

This measures the proportion of the total variation about the mean $\bar{y}$ that can be explained by the regression.

The standard error for the regression constant $\hat{a}$

$$\textbf{a\_serr} = \sqrt{\frac{rss}{df}\left(\frac{1}{\sum w_i} + \frac{(\bar{x})^2}{\sum w_i(x_i - \bar{x})^2}\right)} = \sqrt{\frac{rss}{df}\,\frac{1}{\sum w_i}\,\frac{\sum w_i x_i^2}{\sum w_i(x_i - \bar{x})^2}}.$$

The standard error for the regression coefficient $\hat{b}$

$$\textbf{b\_serr} = \sqrt{\frac{rss}{df\sum w_i(x_i - \bar{x})^2}}.$$

Similar formulae can be derived for the case when the line goes through the origin, that is $a = 0$.

4 References

Draper N R and Smith H (1985) *Applied Regression Analysis* (2nd Edition) Wiley

5 Arguments

1: **mean** – Nag_SumSquare *Input*

On entry: indicates whether nag_simple_linear_regression (g02cac) is to include a constant term in the regression.

mean = Nag_AboutMean
The regression constant a is included.

mean = Nag_AboutZero
The regression constant a is not included, i.e., $a = 0$.

Constraint: **mean** = Nag_AboutMean or Nag_AboutZero.

2: **n** – Integer *Input*

On entry: n, the number of observations.

Constraints:

if **mean** = Nag_AboutMean, **n** ≥ 2;
if **mean** = Nag_AboutZero, **n** ≥ 1.

3: **x**[**n**] – const double *Input*

On entry: the values of the independent variable with the ith value stored in $x[i-1]$, for $i = 1, 2, \ldots, n$.

Constraint: all the values of x must not be identical.

4: **y**[**n**] – const double *Input*

On entry: the values of the dependent variable with the ith value stored in $y[i-1]$, for $i = 1, 2, \ldots, n$.

Constraint: all the values of y must not be identical.

5: **wt**[**n**] – const double *Input*

On entry: if weighted estimates are required then **wt** must contain the weights to be used in the weighted regression. Usually **wt**$[i-1]$ will be an integral value corresponding to the number of observations associated with the ith data point, or zero if the ith data point is to be ignored. The sum of the weights therefore represents the effective total number of observations used to create the regression line.

If weights are not provided then **wt** must be set to **NULL** and the effective number of observations is **n**.

Constraint: if **wt** is not **NULL**, **wt**$[i-1] = 0.0$, for $i = 1, 2, \ldots, n$.

6: **a** – double * *Output*

On exit: if **mean** = Nag_AboutMean then **a** is the regression constant $\hat{a}$, otherwise **a** is set to zero.

7: **b** – double * *Output*

On exit: the regression coefficient $\hat{b}$.

8: **a_serr** – double * *Output*

On exit: the standard error of the regression constant $\hat{a}$.

9: **b_serr** – double * *Output*

On exit: the standard error of the regression coefficient $\hat{b}$.

10: **rsq** – double * *Output*

On exit: the coefficient of determination, R^2.

11: **rss** – double * *Output*

On exit: the sum of squares of the residuals about the regression.

12: **df** – double * *Output*

On exit: the degrees of freedom associated with the residual sum of squares.

13: **fail** – NagError * *Input/Output*

The NAG error argument (see Section 2.7 in How to Use the NAG Library and its Documentation).

6 Error Indicators and Warnings

NE_BAD_PARAM

On entry, argument **mean** had an illegal value.

NE_INT_ARG_LT

On entry, **n** = ⟨*value*⟩.
Constraint: **n** ≥ 1
if **mean** = Nag_AboutZero.

On entry, **n** = ⟨*value*⟩.
Constraint: **n** ≥ 2
if **mean** = Nag_AboutMean.

NE_NEG_WEIGHT

On entry, at least one of the weights is negative.

NE_SW_LOW

On entry, the sum of elements of **wt** must be greater than 1.0 if **mean** = Nag_AboutZero or greater than 2.0 if **mean** = Nag_AboutMean.

NE_WT_LOW

On entry, **wt** must contain at least 1 positive element if **mean** = Nag_AboutZero or at least 2 positive elements if **mean** = Nag_AboutMean.

NE_X_OR_Y_IDEN

On entry, all elements of **x** and/or **y** are equal.

NE_ZERO_DOF_RESID

On entry, the degrees of freedom for the residual are zero, i.e., the designated number of arguments = the effective number of observations.

NW_RSS_EQ_ZERO

Residual sum of squares is zero, i.e., a perfect fit was obtained.

7 Accuracy

The computations are believed to be stable.

8 Parallelism and Performance

nag_simple_linear_regression (g02cac) is not threaded in any implementation.

9 Further Comments

The time taken by the function depends on n. The function uses a two-pass algorithm.

10 Example

A program to calculate regression constants, $\hat{a}$ and $\hat{b}$, the standard error of the regression constants, the regression coefficient of determination and the degrees of freedom about the regression.

10.1 Program Text

```
/* nag_simple_linear_regression (g02cac) Example Program.
 *
 * NAGPRODCODE Version.
 *
 * Copyright 2016 Numerical Algorithms Group.
 *
 * Mark 26, 2016.
 */

#include <nag.h>
#include <stdio.h>
#include <nag_stdlib.h>
#include <nagg02.h>

int main(void)
{
  Integer exit_status = 0, i, n;
  Nag_SumSquare mean;
```

```
  Nag_Boolean weight;
  char nag_enum_arg[40];
  double a, b, df, err_a, err_b, rsq, rss;
  double *wt = 0, *wtptr, *x = 0, *y = 0;
  NagError fail;

  INIT_FAIL(fail);

  printf("nag_simple_linear_regression (g02cac) Example Program Results\n");
  /* Skip heading in data file */
#ifdef _WIN32
  scanf_s("%*[^\n]");
#else
  scanf("%*[^\n]");
#endif
#ifdef _WIN32
  scanf_s(" %39s", nag_enum_arg, (unsigned)_countof(nag_enum_arg));
#else
  scanf(" %39s", nag_enum_arg);
#endif
  /* nag_enum_name_to_value (x04nac).
   * Converts NAG enum member name to value
   */
  mean = (Nag_SumSquare) nag_enum_name_to_value(nag_enum_arg);
#ifdef _WIN32
  scanf_s(" %39s", nag_enum_arg, (unsigned)_countof(nag_enum_arg));
#else
  scanf(" %39s", nag_enum_arg);
#endif
  weight = (Nag_Boolean) nag_enum_name_to_value(nag_enum_arg);
#ifdef _WIN32
  scanf_s("%" NAG_IFMT "", &n);
#else
  scanf("%" NAG_IFMT "", &n);
#endif
  if (n >= (mean == Nag_AboutMean ? 2 : 1)) {
    if (!(x = NAG_ALLOC(n, double)) ||
        !(y = NAG_ALLOC(n, double)) || !(wt = NAG_ALLOC(n, double)))
    {
      printf("Allocation failure\n");
      exit_status = -1;
      goto END;
    }
  }
  else {
    printf("Invalid n.\n");
    exit_status = 1;
    return exit_status;
  }

  if (weight) {
    wtptr = wt;
    for (i = 0; i < n; ++i)
#ifdef _WIN32
      scanf_s("%lf%lf%lf", &x[i], &y[i], &wt[i]);
#else
      scanf("%lf%lf%lf", &x[i], &y[i], &wt[i]);
#endif
  }
  else {
    wtptr = (double *) 0;
    for (i = 0; i < n; ++i)
#ifdef _WIN32
      scanf_s("%lf%lf", &x[i], &y[i]);
#else
      scanf("%lf%lf", &x[i], &y[i]);
#endif
  }

  /* nag_simple_linear_regression (g02cac).
   * Simple linear regression with or without a constant term,
```

```
   * data may be weighted
   */
  nag_simple_linear_regression(mean, n, x, y, wtptr, &a, &b, &err_a, &err_b,
                               &rsq, &rss, &df, &fail);
  if (fail.code != NE_NOERROR) {
    printf("Error from nag_simple_linear_regression (g02cac).\n%s\n",
           fail.message);
    exit_status = 1;
    goto END;
  }

  if (mean == Nag_AboutMean) {
    printf("\nRegression constant a = %6.4f\n\n", a);
    printf("Standard error of the regression constant a = %6.4f\n\n", err_a);
  }

  printf("Regression coefficient b = %6.4f\n\n", b);
  printf("Standard error of the regression coefficient b = %6.4f\n\n", err_b);

  printf("The regression coefficient of determination = %6.4f\n\n", rsq);
  printf("The sum of squares of the residuals about the "
         "regression = %6.4f\n\n", rss);
  printf("Number of degrees of freedom about the "
         "regression = %6.4f\n\n", df);

END:
  NAG_FREE(x);
  NAG_FREE(y);
  NAG_FREE(wt);

  return exit_status;
}
```

10.2 Program Data

```
nag_simple_linear_regression (g02cac) Example Program Data
Nag_AboutMean Nag_TRUE
8
1.0  20.0  1.0
0.0  15.5  1.0
4.0  28.3  1.0
7.5  45.0  1.0
2.5  24.5  1.0
0.0  10.0  1.0
10.0 99.0  1.0
5.0  31.2  1.0
```

10.3 Program Results

```
nag_simple_linear_regression (g02cac) Example Program Results

Regression constant a = 7.5982

Standard error of the regression constant a = 6.6858

Regression coefficient b = 7.0905

Standard error of the regression coefficient b = 1.3224

The regression coefficient of determination = 0.8273

The sum of squares of the residuals about the regression = 965.2454

Number of degrees of freedom about the regression = 6.0000
```