NAG Library Function Document

nag_kruskal_wallis_test (g08afc)

1 Purpose

nag_kruskal_wallis_test (g08afc) performs the Kruskal–Wallis one-way analysis of variance by ranks on k independent samples of possibly unequal sizes.

2 Specification

```
#include <nag.h>
#include <nagg08.h>
```

```
void nag_kruskal_wallis_test (Integer k, const Integer l[], const double x[],
     Integer lx, double *h, double *p, NagError *fail)
```

3 Description

The Kruskal–Wallis test investigates the differences between scores from k independent samples of unequal sizes, the ith sample containing l_i observations. The hypothesis under test, H_0, often called the null hypothesis, is that the samples come from the same population, and this is to be tested against the alternative hypothesis H_1 that they come from different populations.

The test proceeds as follows:

(a) The pooled sample of all the observations is ranked. Average ranks are assigned to tied scores.

(b) The ranks of the observations in each sample are summed, to give the rank sums R_i, for $i = 1, 2, \ldots, k$.

(c) The Kruskal–Wallis' test statistic H is computed as:

$$H = \frac{12}{N(N+1)} \sum_{i=1}^{k} \frac{R_i^2}{l_i} - 3(N+1), \qquad \text{where} N = \sum_{i=1}^{k} l_i,$$

i.e., N is the total number of observations. If there are tied scores, H is corrected by dividing by:

$$1 - \frac{\sum(t^3 - t)}{N^3 - N}$$

where t is the number of tied scores in a group and the summation is over all tied groups.

nag_kruskal_wallis_test (g08afc) returns the value of H, and also an approximation, p, to the probability of a value of at least H being observed, H_0 is true. (H approximately follows a χ^2_{k-1} distribution). H_0 is rejected by a test of chosen size α if $p < \alpha$. The approximation p is acceptable unless $k = 3$ and l_1, l_2 or $l_3 \leq 5$ in which case tables should be consulted (e.g., O of Siegel (1956)) or $k = 2$ (in which case the Median test (see nag_median_test (g08acc)) or the Mann–Whitney U test (see nag_mann_whitney (g08amc)) is more appropriate).

4 References

Moore P G, Shirley E A and Edwards D E (1972) *Standard Statistical Calculations* Pitman

Siegel S (1956) *Non-parametric Statistics for the Behavioral Sciences* McGraw–Hill

5 Arguments

1: **k** – Integer *Input*

On entry: the number of samples, k.

Constraint: $\mathbf{k} \geq 2$.

2: **l**[**k**] – const Integer *Input*

On entry: $\mathbf{l}[i-1]$ must contain the number of observations l_i in sample i, for $i = 1, 2, \ldots, k$.

Constraint: $\mathbf{l}[i-1] > 0$, for $i = 1, 2, \ldots, k$.

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

On entry: the elements of **x** must contain the observations in the **k** groups. The first l_1 elements must contain the scores in the first group, the next l_2 those in the second group, and so on.

4: **lx** – Integer *Input*

On entry: the total number of observations, N.

Constraint: $\mathbf{lx} = \sum_{i=1}^{k} \mathbf{l}[i-1]$.

5: **h** – double * *Output*

On exit: the value of the Kruskal–Wallis test statistic, H.

6: **p** – double * *Output*

On exit: the approximate significance, p, of the Kruskal–Wallis test statistic.

7: **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_ALLOC_FAIL

Dynamic memory allocation failed.

NE_ARRAY_CONS

The contents of array **l** are not valid.
Constraint: $\mathbf{l}[i-1] > 0$, for $i = 1, 2, \ldots, k$.

NE_INT

On entry, $\mathbf{lx} = \langle value \rangle$.
Constraint: $\mathbf{lx} = \sum_{i=1}^{k} \mathbf{l}[i-1]$, for $i = 1, 2, \ldots, k$.

NE_INT_ARG_LT

On entry, $\mathbf{k} = \langle value \rangle$.
Constraint: $\mathbf{k} \geq 2$.

NE_INTERNAL_ERROR

An internal error has occurred in this function. Check the function call and any array sizes. If the call is correct then please contact NAG for assistance.

NE_X_IDEN

On entry, all elements of **x** are equal.

7 Accuracy

For estimates of the accuracy of the significance p, see nag_prob_chi_sq (g01ecc). The χ^2 approximation is acceptable unless $k = 3$ and l_1, l_2 or $l_3 \leq 5$.

8 Parallelism and Performance

nag_kruskal_wallis_test (g08afc) is not threaded in any implementation.

9 Further Comments

The time taken by nag_kruskal_wallis_test (g08afc) is small, and increases with N and k.

If $k = 2$, the Median test (see nag_median_test (g08acc)) or the Mann–Whitney U test (see nag_mann_whitney (g08amc)) is more appropriate.

10 Example

This example is taken from Moore *et al.* Moore *et al.* (1972). There are 5 groups of sizes 5, 8, 6, 8 and 8. The data represent the weight gain, in pounds, of pigs from five different litters under the same conditions.

10.1 Program Text

```
/* nag_kruskal_wallis_test (g08afc) Example Program.
 *
 * NAGPRODCODE Version.
 *
 * Copyright 2016 Numerical Algorithms Group.
 *
 * Mark 26, 2016.
 */

#include <stdio.h>
#include <nag.h>
#include <nag_stdlib.h>
#include <nagg08.h>

int main(void)
{
  Integer count, exit_status = 0, i, ii, k, *l = 0, lx, nhi, ni, nlo;
  NagError fail;
  double h, p, *x = 0;

  INIT_FAIL(fail);

  printf("nag_kruskal_wallis_test (g08afc) Example Program Results\n");

  /* Skip heading in data file */
#ifdef _WIN32
  scanf_s("%*[^\n]");
#else
  scanf("%*[^\n]");
#endif

  k = 5;
  if (!(l = NAG_ALLOC(k, Integer)))
  {
    printf("Allocation failure\n");
    exit_status = -1;
    goto END;
```

```
  }
  for (i = 1; i <= k; i++)
#ifdef _WIN32
    scanf_s("%" NAG_IFMT "", &l[i - 1]);
#else
    scanf("%" NAG_IFMT "", &l[i - 1]);
#endif
  printf("\n");
  printf("%s\n", "Kruskal-Wallis test");
  printf("\n");
  printf("%s\n", "Data values");
  printf("\n");
  printf("%s\n", "  Group    Observations");

  lx = 0;
  for (i = 1; i <= 5; ++i)
    lx += l[i - 1];

  if (!(x = NAG_ALLOC(lx, double)))
  {
    printf("Allocation failure\n");
    exit_status = -1;
    goto END;
  }
  for (i = 1; i <= lx; ++i)
#ifdef _WIN32
    scanf_s("%lf", &x[i - 1]);
#else
    scanf("%lf", &x[i - 1]);
#endif

  nlo = 1;
  for (i = 1; i <= k; ++i) {
    ni = l[i - 1];
    nhi = nlo + ni - 1;
    printf(" %5" NAG_IFMT "      ", i);
    count = 1;
    for (ii = nlo; ii <= nhi; ++ii) {
      printf("%4.0f%s", x[ii - 1], count % 10 ? "" : "\n");
      count++;
    }
    nlo += ni;
    printf("\n");
  }
  /* nag_kruskal_wallis_test (g08afc).
   * Kruskal-Wallis one-way analysis of variance on k samples
   * of unequal size
   */
  nag_kruskal_wallis_test(k, l, x, lx, &h, &p, &fail);
  if (fail.code != NE_NOERROR) {
    printf("Error from nag_kruskal_wallis_test (g08afc).\n%s\n",
           fail.message);
    exit_status = 1;
    goto END;
  }
  printf("\n");
  printf("%s%9.3f\n", "Test statistic        ", h);
  printf("%s%9" NAG_IFMT "\n", "Degrees of freedom    ", k - 1);
  printf("%s%9.3f\n", "Significance          ", p);
END:
  NAG_FREE(l);
  NAG_FREE(x);
  return exit_status;
}
```

10.2 Program Data

```
nag_kruskal_wallis_test (g08afc) Example Program Data
 5 8 6 8 8
 23 27 26 19 30 29 25 33 36 32
 28 30 31 38 31 28 35 33 36 30
 27 28 22 33 34 34 32 31 33 31
 28 30 24 29 30
```

10.3 Program Results

```
nag_kruskal_wallis_test (g08afc) Example Program Results

Kruskal-Wallis test

Data values

  Group    Observations
     1       23  27  26  19  30
     2       29  25  33  36  32  28  30  31
     3       38  31  28  35  33  36
     4       30  27  28  22  33  34  34  32
     5       31  33  31  28  30  24  29  30

Test statistic          10.537
Degrees of freedom           4
Significance             0.032
```