

# NAG Library Function Document

## nag\_quicksort (m01csc)

### 1 Purpose

nag\_quicksort (m01csc) rearranges a vector of arbitrary type objects into ascending or descending order.

### 2 Specification

```
#include <nag.h>
#include <nagm01.h>

void nag_quicksort (Pointer vec, size_t n, size_t size, ptrdiff_t stride,
                   Integer (*compare)(const Nag_Pointer a, const Nag_Pointer b),
                   Nag_SortOrder order, NagError *fail)
```

### 3 Description

nag\_quicksort (m01csc) sorts a set of  $n$  data objects of arbitrary type, which are stored in the elements of an array at intervals of length **stride**. The function may be used to sort a column of a two-dimensional array. Either ascending or descending sort order may be specified.

nag\_quicksort (m01csc) is based on Singleton's implementation of the 'median-of-three' Quicksort algorithm, Singleton (1969), but with two additional modifications. First, small subfiles are sorted by an insertion sort on a separate final pass, Sedgewick (1978). Second, if a subfile is partitioned into two very unbalanced subfiles, the larger of them is flagged for special treatment: before it is partitioned, its end-points are swapped with two random points within it; this makes the worst case behaviour extremely unlikely.

### 4 References

Maclaren N M (1985) *Comput. J.* **28** 448

Sedgewick R (1978) Implementing Quicksort programs *Comm. ACM* **21** 847–857

Singleton R C (1969) An efficient algorithm for sorting with minimal storage: Algorithm 347 *Comm. ACM* **12** 185–187

### 5 Arguments

- 1: **vec[n]** – Pointer *Input/Output*  
*On entry:* the array of objects to be sorted.  
*On exit:* the objects rearranged into sorted order.
  
- 2: **n** – size\_t *Input*  
*On entry:* the number,  $n$ , of objects to be sorted.  
*Constraint:*  $0 \leq n \leq \text{MAX\_LENGTH}$ , where MAX\_LENGTH is an implementation-dependent value for the maximum size of an array.

3: **size** – size\_t *Input*

*On entry:* the size of each object to be sorted.

*Constraint:*  $1 \leq \mathbf{size} \leq p$ , where  $p$  is an implementation-dependent value for the maximum size\_t size on the system, divided by  $\mathbf{n}$  if  $\mathbf{n}$  is positive.

4: **stride** – ptrdiff\_t *Input*

*On entry:* the increment between data items in **vec** to be sorted.

**Note:** if **stride** is positive, **vec** should point at the first data object; otherwise **vec** should point at the last data object.

*Constraint:*  $\mathbf{size} \leq |\mathbf{stride}| \leq p$ , where  $p$  is an implementation-dependent value for the maximum size\_t size on the system, divided by  $\mathbf{n}$  if  $\mathbf{n}$  is positive.

5: **compare** – function, supplied by the user *External Function*

nag\_quicksort (m01csc) compares two data objects. If its arguments are pointers to a structure, this function must allow for the offset of the data field in the structure (if it is not the first).

The function must return:

- 1 if the first data field is less than the second,
- 0 if the first data field is equal to the second,
- 1 if the first data field is greater than the second.

The specification of **compare** is:

```
Integer compare (const Nag_Pointer a, const Nag_Pointer b)
```

1: **a** – const Nag\_Pointer *Input*

*On entry:* the first data field.

2: **b** – const Nag\_Pointer *Input*

*On entry:* the second data field.

6: **order** – Nag\_SortOrder *Input*

*On entry:* specifies whether the array is to be sorted into ascending or descending order.

*Constraint:* **order** = Nag\_Ascending or Nag\_Descending.

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\_2\_INT\_ARG\_LT

On entry,  $|\mathbf{stride}| = \langle \text{value} \rangle$  while  $\mathbf{size} = \langle \text{value} \rangle$ . These arguments must satisfy  $|\mathbf{stride}| \geq \mathbf{size}$ .

### NE\_ALLOC\_FAIL

Dynamic memory allocation failed.

### NE\_BAD\_PARAM

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

**NE\_INT\_ARG\_GT**

On entry, `|stride| = <value>`.

Constraint: `|stride| ≤ <value>`, an implementation-dependent size that is printed in the error message.

On entry, `n = <value>`.

Constraint: `n ≤ <value>`, an implementation-dependent size that is printed in the error message.

On entry, `size = <value>`.

Constraint: `size ≤ <value>`, an implementation-dependent size that is printed in the error message.

**NE\_INT\_ARG\_LT**

On entry, `n = <value>`.

Constraint: `n ≥ 0`.

On entry, `size = <value>`.

Constraint: `size ≥ 1`.

**7 Accuracy**

Not applicable.

**8 Parallelism and Performance**

`nag_quicksort (m01csc)` is not threaded in any implementation.

**9 Further Comments**

The average time taken by the function is approximately proportional to  $n \log(n)$ . The worst case time is proportional to  $n^2$  but this is extremely unlikely to occur.

**10 Example**

The example program reads a two-dimensional array of numbers and sorts the second column into ascending order.

**10.1 Program Text**

```

/* nag_quicksort (m01csc) Example Program.
 *
 * NAGPRODCODE Version.
 *
 * Copyright 2016 Numerical Algorithms Group.
 *
 * Mark 26, 2016.
 */

#include <nag.h>
#include <stdio.h>
#include <nag_stdlib.h>
#include <nag_stddef.h>
#include <nagm01.h>

#ifdef __cplusplus
extern "C"
{
#endif
    static Integer NAG_CALL compare(const Nag_Pointer a, const Nag_Pointer b);
#ifdef __cplusplus
}
#endif

```

```

#define VEC(I, J) vec[(I) *tdvec + J]
int main(void)
{
    Integer exit_status = 0, i, j, k, m, n, tdvec;
    double *vec = 0;
    NagError fail;

    INIT_FAIL(fail);

    /* Skip heading in data file */
#ifdef _WIN32
    scanf_s("%*[\n]");
#else
    scanf("%*[\n]");
#endif
    printf("nag_quicksort (m01csc) Example Program Results\n");
#ifdef _WIN32
    scanf_s("%" NAG_IFMT "", &m);
#else
    scanf("%" NAG_IFMT "", &m);
#endif
#ifdef _WIN32
    scanf_s("%" NAG_IFMT "", &n);
#else
    scanf("%" NAG_IFMT "", &n);
#endif
#ifdef _WIN32
    scanf_s("%" NAG_IFMT "", &k);
#else
    scanf("%" NAG_IFMT "", &k);
#endif
    if (m >= 1 && n >= 1 && k >= 1) {
        if (!(vec = NAG_ALLOC(m * n, double)))
        {
            printf("Allocation failure\n");
            exit_status = -1;
            goto END;
        }
        tdvec = n;
    }
    else {
        printf("Invalid m or n or k.\n");
        exit_status = 1;
        return exit_status;
    }
    for (i = 0; i < m; ++i)
        for (j = 0; j < n; ++j)
#ifdef _WIN32
            scanf_s("%lf", &VEC(i, j));
#else
            scanf("%lf", &VEC(i, j));
#endif
    /* nag_quicksort (m01csc).
     * Quicksort of set of values of arbitrary data type
     */
    nag_quicksort((Pointer) &VEC(0, k - 1), (size_t) m, sizeof(double),
                  (ptrdiff_t) (sizeof(double) * n), compare, Nag_Ascending,
                  &fail);
    if (fail.code != NE_NOERROR) {
        printf("Error from nag_quicksort (m01csc).\n%s\n", fail.message);
        exit_status = 1;
        goto END;
    }
    printf("\nMatrix with column %" NAG_IFMT " sorted \n", k);
    for (i = 0; i < m; ++i) {
        for (j = 0; j < n; ++j)
            printf(" %8.1f ", VEC(i, j));
        printf("\n");
    }
}
END:

```

```

    NAG_FREE(vec);

    return exit_status;
}

static Integer NAG_CALL compare(const Nag_Pointer a, const Nag_Pointer b)
{
    double x = *((const double *) a);
    double y = *((const double *) b);
    return (x < y ? -1 : (x == y ? 0 : 1));
}

```

## 10.2 Program Data

nag\_quicksort (m01csc) Example Program Data

```

12 3 2
 6.0      5.0      4.0
 5.0      2.0      1.0
 2.0      4.0      9.0
 4.0      9.0      6.0
 4.0      9.0      5.0
 4.0      1.0      2.0
 3.0      4.0      1.0
 2.0      4.0      6.0
 1.0      6.0      4.0
 9.0      3.0      2.0
 6.0      2.0      5.0
 4.0      9.0      6.0

```

## 10.3 Program Results

nag\_quicksort (m01csc) Example Program Results

```

Matrix with column 2 sorted
 6.0      1.0      4.0
 5.0      2.0      1.0
 2.0      2.0      9.0
 4.0      3.0      6.0
 4.0      4.0      5.0
 4.0      4.0      2.0
 3.0      4.0      1.0
 2.0      5.0      6.0
 1.0      6.0      4.0
 9.0      9.0      2.0
 6.0      9.0      5.0
 4.0      9.0      6.0

```

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