

NAG Library Function Document

nag_cubic_roots (c02akc)

1 Purpose

nag_cubic_roots (c02akc) determines the roots of a cubic equation with real coefficients.

2 Specification

```
#include <nag.h>
#include <nagc02.h>
void nag_cubic_roots (double u, double r, double s, double t, double zeror[],
                     double zeroi[], double errest[], NagError *fail)
```

3 Description

nag_cubic_roots (c02akc) attempts to find the roots of the cubic equation

$$uz^3 + rz^2 + sz + t = 0,$$

where u, r, s and t are real coefficients with $u \neq 0$. The roots are located by finding the eigenvalues of the associated 3 by 3 (upper Hessenberg) companion matrix² H given by

$$H = \begin{pmatrix} 0 & 0 & -t/u \\ 1 & 0 & -s/u \\ 0 & 1 & -r/u \end{pmatrix}.$$

Further details can be found in Section 9.

To obtain the roots of a quadratic equation, nag_quartic_roots (c02alc) can be used.

4 References

Golub G H and Van Loan C F (1996) *Matrix Computations* (3rd Edition) Johns Hopkins University Press, Baltimore

5 Arguments

- | | | |
|----|---|--------------|
| 1: | u – double | <i>Input</i> |
| | <i>On entry:</i> u , the coefficient of z^3 . | |
| | <i>Constraint:</i> $u \neq 0.0$. | |
| 2: | r – double | <i>Input</i> |
| | <i>On entry:</i> r , the coefficient of z^2 . | |
| 3: | s – double | <i>Input</i> |
| | <i>On entry:</i> s , the coefficient of z . | |
| 4: | t – double | <i>Input</i> |
| | <i>On entry:</i> t , the constant coefficient. | |

- 5: **zeror**[3] – double *Output*
- 6: **zeroi**[3] – double *Output*
- On exit:* **zeror**[$i - 1$] and **zeroi**[$i - 1$] contain the real and imaginary parts, respectively, of the i th root.
- 7: **errest**[3] – double *Output*
- On exit:* **errest**[$i - 1$] contains an approximate error estimate for the i th root.
- 8: **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_C02_NOT_CONV

The iterative procedure used to determine the eigenvalues has failed to converge.

NE_C02_OVERFLOW

The companion matrix H cannot be formed without overflow.

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_REAL

On entry, $\mathbf{u} = 0.0$.
Constraint: $\mathbf{u} \neq 0.0$.

7 Accuracy

If **fail.code** = NE_NOERROR on exit, then the i th computed root should have approximately $|\log_{10}(\mathbf{errest}[i - 1])|$ correct significant digits.

8 Parallelism and Performance

nag_cubic_roots (c02akc) is not threaded in any implementation.

9 Further Comments

The method used by the function consists of the following steps, which are performed by functions from LAPACK.

- (a) Form H .
- (b) Apply a diagonal similarity transformation to H (to give H').
- (c) Calculate the eigenvalues and Schur factorization of H' .
- (d) Calculate the left and right eigenvectors of H' .
- (e) Estimate reciprocal condition numbers for all the eigenvalues of H' .
- (f) Calculate approximate error estimates for all the eigenvalues of H' (using the 1-norm).

10 Example

To find the roots of the cubic equation

$$z^3 + 3z^2 + 9z - 13 = 0.$$

10.1 Program Text

```

/* nag_cubic_roots (c02akc) Example Program.
 *
 * NAGPRODCODE Version.
 *
 * Copyright 2016 Numerical Algorithms Group.
 *
 * NAG C Library
 *
 * Mark 26, 2016.
 */

#include <stdio.h>
#include <nag.h>
#include <nag_stdlib.h>
#include <nagc02.h>

int main(void)
{
    double *errest = 0, *zeroi = 0, *zeror = 0;
    double r, s, t, u;
    Integer i;
    Integer exit_status = 0;
    NagError fail;

    INIT_FAIL(fail);

    printf("nag_cubic_roots (c02akc) Example Program Results\n\n");

    if (!(errest = NAG_ALLOC(3, double)) ||
        !(zeroi = NAG_ALLOC(3, double)) || !(zeror = NAG_ALLOC(3, double))
        )
    {
        printf("Allocation failure\n");
        exit_status = -1;
        goto END;
    }

    /* Skip heading in data file */
#ifdef _WIN32
    scanf_s("%*[\n] ");
#else
    scanf("%*[\n] ");
#endif
#ifdef _WIN32
    scanf_s("%lf %lf %lf %lf ", &u, &r, &s, &t);
#else
    scanf("%lf %lf %lf %lf ", &u, &r, &s, &t);
#endif

    /* nag_cubic_roots (c02akc).
     * Zeros of a cubic polynomial with real coefficients
     */
    nag_cubic_roots(u, r, s, t, zeror, zeroi, errest, &fail);
    if (fail.code == NE_NOERROR) {
        printf("\n Roots of cubic equation           Error estimates\n");
        printf("                                (machine-dependent)\n\n");
        for (i = 0; i <= 2; ++i) {
            printf(" z = %10.5f %10.5f%s           %g\n",
                zeror[i], zeroi[i], " *i", errest[i]);
        }
    }
    else {

```

```

    printf("Error from nag_cubic_roots (c02akc).\n%s\n", fail.message);
    exit_status = 1;
    goto END;
}

END:
NAG_FREE(errest);
NAG_FREE(zeroi);
NAG_FREE(zeror);
return exit_status;
}

```

10.2 Program Data

nag_cubic_roots (c02akc) Example Program Data
 1.0 3.0 9.0 -13.0 : Values of u, r, s and t

10.3 Program Results

nag_cubic_roots (c02akc) Example Program Results

Roots of cubic equation	Error estimates (machine-dependent)
z = 1.00000 0.00000*i	2.37922e-15
z = -2.00000 3.00000*i	3.08789e-15
z = -2.00000 -3.00000*i	3.08789e-15
