

# NAG Library Function Document

## nag\_1d\_pade\_eval (e02rbc)

### 1 Purpose

nag\_1d\_pade\_eval (e02rbc) evaluates a rational function at a user-supplied point, given the numerator and denominator coefficients.

### 2 Specification

```
#include <nag.h>
#include <nage02.h>

void nag_1d_pade_eval (const double a[], Integer ia, const double b[],
                      Integer ib, double x, double *ans, NagError *fail)
```

### 3 Description

Given a real value  $x$  and the coefficients  $a_j$ , for  $j = 0, 1, \dots, l$  and  $b_k$ , for  $k = 0, 1, \dots, m$ , nag\_1d\_pade\_eval (e02rbc) evaluates the rational function

$$\frac{\sum_{j=0}^l a_j x^j}{\sum_{k=0}^m b_k x^k}.$$

using nested multiplication (see Conte and de Boor (1965)).

A particular use of nag\_1d\_pade\_eval (e02rbc) is to compute values of the Padé approximants determined by nag\_1d\_pade (e02rac).

### 4 References

Conte S D and de Boor C (1965) *Elementary Numerical Analysis* McGraw–Hill

Peters G and Wilkinson J H (1971) Practical problems arising in the solution of polynomial equations *J. Inst. Maths. Applics.* **8** 16–35

### 5 Arguments

- 1: **a[ia]** – const double *Input*  
*On entry:* **a[j]**, for  $j = 1, 2, \dots, l + 1$ , must contain the value of the coefficient  $a_j$  in the numerator of the rational function.
- 2: **ia** – Integer *Input*  
*On entry:* the value of  $l + 1$ , where  $l$  is the degree of the numerator.  
*Constraint:* **ia**  $\geq 1$ .
- 3: **b[ib]** – const double *Input*  
*On entry:* **b[k]**, for  $k = 1, 2, \dots, m + 1$ , must contain the value of the coefficient  $b_k$  in the denominator of the rational function.  
*Constraint:* if **ib** = 1, **b[0]**  $\neq 0.0$ .

- 4: **ib** – Integer *Input*  
*On entry:* the value of  $m + 1$ , where  $m$  is the degree of the denominator.  
*Constraint:* **ib**  $\geq 1$ .
- 5: **x** – double *Input*  
*On entry:* the point  $x$  at which the rational function is to be evaluated.
- 6: **ans** – double \* *Output*  
*On exit:* the result of evaluating the rational function at the given point  $x$ .
- 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.

See Section 3.2.1.2 in How to Use the NAG Library and its Documentation for further information.

### NE\_BAD\_PARAM

On entry, argument  $\langle value \rangle$  had an illegal value.

### NE\_INT

On entry, **ia** =  $\langle value \rangle$ .

Constraint: **ia**  $\geq 1$ .

On entry, **ib** =  $\langle value \rangle$ .

Constraint: **ib**  $\geq 1$ .

### NE\_INT\_ARRAY

The first **ib** entries in **b** are zero: **ib** =  $\langle value \rangle$ .

### 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.

An unexpected error has been triggered by this function. Please contact NAG.

See Section 3.6.6 in How to Use the NAG Library and its Documentation for further information.

### NE\_NO\_LICENCE

Your licence key may have expired or may not have been installed correctly.

See Section 3.6.5 in How to Use the NAG Library and its Documentation for further information.

### NE\_POLE\_PRESENT

Evaluation at or near a pole.

## 7 Accuracy

A running error analysis for polynomial evaluation by nested multiplication using the recurrence suggested by Kahan (see Peters and Wilkinson (1971)) is used to detect whether you are attempting to evaluate the approximant at or near a pole.

## 8 Parallelism and Performance

nag\_1d\_pade\_eval (e02rbc) is not threaded in any implementation.

## 9 Further Comments

The time taken is approximately proportional to  $l + m$ .

## 10 Example

This example first calls nag\_1d\_pade (e02rac) to calculate the 4/4 Padé approximant to  $e^x$ , and then uses nag\_1d\_pade\_eval (e02rbc) to evaluate the approximant at  $x = 0.1, 0.2, \dots, 1.0$ .

### 10.1 Program Text

```

/* nag_1d_pade_eval (e02rbc) Example Program.
 *
 * NAGPRODCODE Version.
 *
 * Copyright 2016 Numerical Algorithms Group.
 *
 * Mark 26, 2016.
 */

#include <stdio.h>
#include <math.h>
#include <nag.h>
#include <nag_stdlib.h>
#include <nage02.h>

int main(void)
{
    /* Scalars */
    double ans, tval, x;
    Integer exit_status, i, l, m, ia, ib, ic;
    NagError fail;

    /* Arrays */
    double *aa = 0, *bb = 0, *cc = 0;

    INIT_FAIL(fail);

    exit_status = 0;
    printf("nag_1d_pade_eval (e02rbc) Example Program Results\n");

    l = 4;
    m = 4;
    ia = l + 1;
    ib = m + 1;
    ic = ia + ib - 1;

    /* Allocate memory */
    if (!(aa = NAG_ALLOC(ia, double)) ||
        !(bb = NAG_ALLOC(ib, double)) || !(cc = NAG_ALLOC(ic, double)))
    {
        printf("Allocation failure\n");
        exit_status = -1;
        goto END;
    }
}

```

```

cc[0] = 1.0;
for (i = 1; i <= ic - 1; ++i)
    cc[i] = cc[i - 1] / (double) i;

/* nag_ld_pade (e02rac).
 * Pade-approximants
 */
nag_ld_pade(ia, ib, cc, aa, bb, &fail);
if (fail.code != NE_NOERROR) {
    printf("Error from nag_ld_pade (e02rac).\n%s\n", fail.message);
    exit_status = 1;
    goto END;
}

printf("\n");
printf("    x          Pade          True\n");

for (i = 0; i < 10; ++i) {
    x = (double) (i + 1) / 10.0;
    /* nag_ld_pade_eval (e02rbc).
     * Evaluation of fitted rational function as computed by
     * nag_ld_pade (e02rac)
     */
    nag_ld_pade_eval(aa, ia, bb, ib, x, &ans, &fail);
    if (fail.code != NE_NOERROR) {
        printf("Error from nag_ld_pade_eval (e02rbc).\n%s\n", fail.message);
        exit_status = 1;
        goto END;
    }

    tval = exp(x);
    printf("%6.1f%15.5e%15.5e\n", x, ans, tval);
}

END:
NAG_FREE(aa);
NAG_FREE(bb);
NAG_FREE(cc);

return exit_status;
}

```

## 10.2 Program Data

None.

## 10.3 Program Results

nag\_ld\_pade\_eval (e02rbc) Example Program Results

x	Pade	True
0.1	1.10517e+00	1.10517e+00
0.2	1.22140e+00	1.22140e+00
0.3	1.34986e+00	1.34986e+00
0.4	1.49182e+00	1.49182e+00
0.5	1.64872e+00	1.64872e+00
0.6	1.82212e+00	1.82212e+00
0.7	2.01375e+00	2.01375e+00
0.8	2.22554e+00	2.22554e+00
0.9	2.45960e+00	2.45960e+00
1.0	2.71828e+00	2.71828e+00

