NAG Library Function Document

nag_polygamma_fun (s14acc)

1 Purpose

nag_polygamma_fun (s14acc) returns a value of the function $\psi(x) - \ln x$, where ψ is the psi function $\psi(x) = \dfrac{d}{dx}\ln\Gamma(x) = \dfrac{\Gamma'(x)}{\Gamma(x)}$.

2 Specification

```
#include <nag.h>
#include <nags.h>
double nag_polygamma_fun (double x, NagError *fail)
```

3 Description

nag_polygamma_fun (s14acc) returns a value of the function $\psi(x) - \ln x$. The psi function is computed without the logarithmic term so that when x is large, sums or differences of psi functions may be computed without unnecessary loss of precision, by analytically combining the logarithmic terms. For example, the difference $d = \psi\left(x + \frac{1}{2}\right) - \psi(x)$ has an asymptotic behaviour for large x given by $d \sim \ln\left(x + \frac{1}{2}\right) - \ln x + O\left(\dfrac{1}{x^2}\right) \sim \ln\left(1 + \dfrac{1}{2x}\right) \sim \dfrac{1}{2x}$.

Computing d directly would amount to subtracting two large numbers which are close to $\ln\left(x + \frac{1}{2}\right)$ and $\ln x$ to produce a small number close to $\frac{1}{2x}$, resulting in a loss of significant digits. However, using this function to compute $f(x) = \psi(x) - \ln x$, we can compute $d = f\left(x + \frac{1}{2}\right) - f(x) + \ln\left(1 + \frac{1}{2x}\right)$, and the dominant logarithmic term may be computed accurately from its power series when x is large. Thus we avoid the unnecessary loss of precision.

The function is derived from the function PSIFN in Amos (1983).

4 References

Abramowitz M and Stegun I A (1972) *Handbook of Mathematical Functions* (3rd Edition) Dover Publications

Amos D E (1983) Algorithm 610: A portable FORTRAN subroutine for derivatives of the psi function *ACM Trans. Math. Software* **9** 494–502

5 Arguments

1: **x** – double *Input*

On entry: the argument x of the function.

Constraint: **x** > 0.0.

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

The NAG error argument (see Section 3.6 in the Essential Introduction).

6 Error Indicators and Warnings

NE_ALLOC_FAIL

Dynamic memory allocation failed.

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_OVERFLOW_LIKELY

Computation halted due to likelihood of overflow. **x** may be too small. **x** $= \langle value \rangle$.

NE_REAL

On entry, **x** $= \langle value \rangle$.
Constraint: **x** > 0.0.

NE_UNDERFLOW_LIKELY

Computation halted due to likelihood of underflow. **x** may be too large. **x** $= \langle value \rangle$.

7 Accuracy

All constants in nag_polygamma_fun (s14acc) are given to approximately 18 digits of precision. Calling the number of digits of precision in the floating-point arithmetic being used t, then clearly the maximum number of correct digits in the results obtained is limited by $p = \min(t, 18)$.

With the above proviso, results returned by this function should be accurate almost to full precision, except at points close to the zero of $\psi(x)$, $x \simeq 1.461632$, where only absolute rather than relative accuracy can be obtained.

8 Parallelism and Performance

Not applicable.

9 Further Comments

None.

10 Example

The example program reads values of the argument x from a file, evaluates the function at each value of x and prints the results.

10.1 Program Text

```
/* nag_polygamma_fun (s14acc) Example Program.
 *
 * Copyright 2002 Numerical Algorithms Group.
 *
 * Mark 7, 2002.
 */

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

int main(void)
{
```

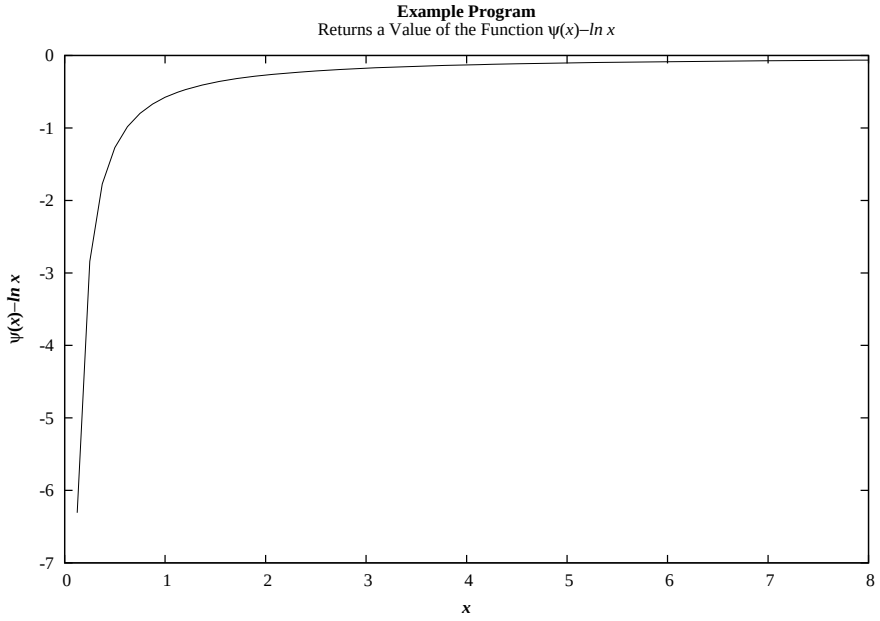
```
  Integer  exit_status = 0;
  double   f, x;
  NagError fail;

  INIT_FAIL(fail);

  /* Skip heading in data file */
  scanf("%*[^\n]");
  printf("nag_polygamma_fun (s14acc) Example Program Results\n");
  printf("     x       psi(x)-log(x)\n");
  while (scanf("%lf", &x) != EOF)
    {
      /* nag_polygamma_fun (s14acc).
       * psi(x) - ln(x)
       */
      f = nag_polygamma_fun(x, &fail);
      if (fail.code != NE_NOERROR)
        {
          printf("Error from nag_polygamma_fun (s14acc).\n%s\n",
                  fail.message);
          exit_status = 1;
          goto END;
        }
      printf("%8.3f %14.4f\n", x, f);
    }

 END:
  return exit_status;
}
```

10.2 Program Data

```
nag_polygamma_fun (s14acc) Example Program Data
0.1
0.5
3.6
8.0
```

10.3 Program Results

```
nag_polygamma_fun (s14acc) Example Program Results
     x       psi(x)-log(x)
   0.100        -8.1212
   0.500        -1.2704
   3.600        -0.1453
   8.000        -0.0638
```


Example Program
Returns a Value of the Function ψ(x)–ln x
0
-1
-2
-3
-4
-5
-6
-7
ψ(x)–ln x
0
1
2
3
4
5
6
7
8
x