NAG Library Function Document

nag_real_symm_sparse_eigensystem_option (f12fdc)

Note: this function uses optional arguments to define choices in the problem specification. If you wish to use default settings for all of the optional arguments, then this function need not be called. If, however, you wish to reset some or all of the settings please refer to Section 11 for a detailed description of the specification of the optional arguments.

1 Purpose

nag_real_symm_sparse_eigensystem_option (f12fdc) is an option setting function in a suite of functions consisting of nag_real_symm_sparse_eigensystem_init (f12fac), nag_real_symm_sparse_eigensystem_iter (f12fbc), nag_real_symm_sparse_eigensystem_sol (f12fcc), and may be used to supply individual optional arguments to nag_real_symm_sparse_eigensystem_init (f12fac) and nag_real_symm_sparse_eigensystem_sol (f12fcc). The initialization function nag_real_symm_sparse_eigensystem_init (f12fac) must have been called prior to calling nag_real_symm_sparse_eigensystem_option (f12fdc).

2 Specification

#include <nag.h>
#include <nagf12.h>

void nag_real_symm_sparse_eigensystem_option (const char *str, 
Integer icomm[], double comm[], NagError *fail)

3 Description

nag_real_symm_sparse_eigensystem_option (f12fdc) may be used to supply values for optional arguments to nag_real_symm_sparse_eigensystem_iter (f12fbc) and nag_real_symm_sparse_eigensystem_sol (f12fcc). It is only necessary to call nag_real_symm_sparse_eigensystem_option (f12fdc) for those arguments whose values are to be different from their default values. One call to nag_real_symm_sparse_eigensystem_option (f12fdc) sets one argument value.

Each optional argument is defined by a single character string consisting of one or more items. The items associated with a given option must be separated by spaces, or equals signs [=]. Alphabetic characters may be upper or lower case. The string

‘Iteration Limit = 500’

is an example of a string used to set an optional argument. For each option the string contains one or more of the following items:

- a mandatory keyword;
- a phrase that qualifies the keyword;
- a number that specifies an Integer or double value. Such numbers may be up to 16 contiguous characters in C’s d or g format.

nag_real_symm_sparse_eigensystem_option (f12fdc) does not have an equivalent function from the ARPACK package which passes options by directly setting values to scalar arguments or to specific elements of array arguments. nag_real_symm_sparse_eigensystem_option (f12fdc) is intended to make the passing of options more transparent and follows the same principle as the single option setting functions in Chapter e04.

The setup function nag_real_symm_sparse_eigensystem_init (f12fac) must be called prior to the first call to nag_real_symm_sparse_eigensystem_option (f12fdc) and all calls to
nag_real_symm_sparse_eigensystem_option (f12fdc) must precede the first call to nag_real_symm_sparse_eigensystem_iter (f12fbc), the reverse communication iterative solver.

A complete list of optional arguments, their abbreviations, synonyms and default values is given in Section 11.

4 References


5 Arguments

1:  str – const char *  
   On entry: a single valid option string (as described in Section 3 and Section 11).

2:  icomm[dim] – Integer  
   Communication Array
   Note: the dimension, dim, of the array icomm must be at least max\(1,\text{licomm}\) (see nag_real_symm_sparse_eigensystem_init (f12fac)).
   On initial entry: must remain unchanged following a call to the setup function nag_real_symm_sparse_eigensystem_init (f12fac).
   On exit: contains data on the current options set.

3:  comm[dim] – double  
   Communication Array
   Note: the dimension, dim, of the array comm must be at least 60.
   On initial entry: must remain unchanged following a call to the setup function nag_real_symm_sparse_eigensystem_init (f12fac).
   On exit: contains data on the current options set.

4:  fail – NagError *  
   The NAG error argument (see Section 3.6 in the Essential Introduction).

6 Error Indicators and Warnings

NE_ALLOC_FAIL
   Dynamic memory allocation failed.
   See Section 3.2.1.2 in the Essential Introduction for further information.

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

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 the Essential Introduction for further information.

**NE_INVALID_OPTION**

Ambiguous keyword: \( \langle value \rangle \)

Keyword not recognized: \( \langle value \rangle \)

Second keyword not recognized: \( \langle value \rangle \)

**NE_NO_LICENCE**

Your licence key may have expired or may not have been installed correctly. See Section 3.6.5 in the Essential Introduction for further information.

7 Accuracy

Not applicable.

8 Parallelism and Performance

Not applicable.

9 Further Comments

None.

10 Example

This example solves \( Ax = \lambda Bx \) in **Shifted Inverse** mode, where \( A \) and \( B \) are obtained from the standard central difference discretization of the one-dimensional Laplacian operator \( \frac{\partial^2 u}{\partial x^2} \) on \([0,1]\), with zero Dirichlet boundary conditions. Data is passed to and from the reverse communication function `nag_real_symm_sparse_eigensystem_iter (f12fbc)` using pointers to the communication array.

10.1 Program Text

```c
/* nag_real_symm_sparse_eigensystem_option (f12fdc) Example Program. */
/* Copyright 2014 Numerical Algorithms Group. */
/* Mark 8, 2005. */

#include <math.h>
#include <nag.h>
#include <nag_stdlib.h>
#include <stdio.h>
#include <nagf12.h>
#include <nagf16.h>

static void mv(Integer, double *, double *);
static void my_dgttrf(Integer, double *, double *, double *,
                       double *, Integer *, Integer *);
static void my_dgttrs(Integer, double *, double *, double *,
                       double *, Integer *, double *, double *);

int main(void)
{
    /* Constants */
    Integer licomm = 140, imon = 0;

    /* Scalars */
    double estnrm, h, r1, r2, sigma;
```
Integer exit_status, info, irevcm, j, lcomm, n, nconv, ncv;
Integer nconv, niter, nshift;
/* Nag types */
NagError fail;
/* Arrays */
double *dd = 0, *dl = 0, *du = 0, *du2 = 0, *comm = 0, *eigest = 0;
double *eigv = 0, *resid = 0, *v = 0, *x2 = 0;
Integer *icomm = 0, *ipiv = 0;
/* Pointers */
double *mx = 0, *x = 0, *y = 0;
exit_status = 0;
INIT_FAIL(fail);
printf("nag_real_symm_sparse_eigensystem_option (f12fdc) Example ",
        "Program Results\n");
#ifdef _WIN32
scanf_s("%*[\n ] ");
#else
scanf("%*[\n ] ");
#endif
/* Read values for nx, nev and cnv from data file. */
#ifdef _WIN32
scanf_s("%"NAG_IFMT"%"NAG_IFMT"%"NAG_IFMT"%*[\n ] ", &n, &nev, &ncv);
#else
scanf("%"NAG_IFMT"%"NAG_IFMT"%"NAG_IFMT"%*[\n ] ", &n, &nev, &ncv);
#endif
/* Allocate memory */
lcomm = 3*n + ncv*ncv + 8*ncv + 60;
if (!(dd = NAG_ALLOC(n, double)) ||
    !(dl = NAG_ALLOC(n, double)) ||
    !(du = NAG_ALLOC(n, double)) ||
    !(du2 = NAG_ALLOC(n, double)) ||
    !(comm = NAG_ALLOC(lcomm, double)) ||
    !(eigest = NAG_ALLOC(ncv, double)) ||
    !(eigv = NAG_ALLOC(ncv, double)) ||
    !(resid = NAG_ALLOC(n, double)) ||
    !(v = NAG_ALLOC(n * ncv, double)) ||
    !(x2 = NAG_ALLOC(n, double)) ||
    !(icomm = NAG_ALLOC(lcomm, Integer)) ||
    !(ipiv = NAG_ALLOC(n, Integer)))
{
    printf("Allocation failure\n");
    exit_status = -1;
    goto END;
}
/* Initialise communication arrays for problem using
nag_real_symm_sparse_eigensystem_init (f12fac). */
#pragmaalg
nag_real_symm_sparse_eigensystem_init(n, nev, ncv, icomm, licomm, comm, 
                                lcomm, &fail);
if (fail.code != NE_NOERROR)
{
    printf("Error from nag_real_symm_sparse_eigensystem_init (f12fac).\n", fail.message);
    exit_status = 1;
    goto END;
}
/* Select the problem type using
nag_real_symm_sparse_eigensystem_option (f12fdc). */
#pragmaalg
nag_real_symm_sparse_eigensystem_option("generalized", icomm, comm, &fail);

/* Select the operating mode using
nag_real_symm_sparse_eigensystem_option (f12fdc). */
#pragmaalg
nag_real_symm_sparse_eigensystem_option("shifted inverse", icomm, comm, 
                                &fail);
if (fail.code != NE_NOERROR)
{
}
printf("Error from nag_real_symm_sparse_eigensystem_option (f12fdc).\n%s\n",
fail.message);
exit_status = 1;
goto END;
}
/* Setup M and factorise */
h = 1.0 / (double)(n + 1);
rl = 2.0 * h / 3.0;
r2 = h / 6.0;
sigma = 0.0;
for (j = 0; j <= n-1; ++j)
{
    dd[j] = 2.0 / h - sigma * rl;
dl[j] = -1.0 / h - sigma * r2;
    du[j] = dl[j];
}
my_dgttrf(n, dl, dd, du, du2, ipiv, &info);
irevcnm = 0;
REVCOMLOOP:
/* Repeated calls to reverse communication routine
nag_real_symm_sparse_eigensystem_iter (f12fbc). */
nag_real_symm_sparse_eigensystem_iter(&irevcnm, resid, v, &x, &y, &mx,
&nshift, comm, icomm, &fail);
if (irevcnm != 5)
{
    if (irevcnm == -1)
    {
        /* Perform y <--- OP*x = inv[A-SIGMA*M]*M*x. */
        mv(n, x, x2);
        my_dgttrs(n, dl, dd, du, du2, ipiv, x2, y);
    }
    else if (irevcnm == 1)
    {
        /* Perform y <-- OP*x = inv[A-sigma*M]*M*x;
        M*x has been saved in COMM(ICOMM(3)) or MX. */
        my_dgttrs(n, dl, dd, du, du2, ipiv, mx, y);
    }
    else if (irevcnm == 2)
    {
        /* Perform y <--- M*x. */
        mv(n, x, y);
    }
    else if (irevcnm == 4 && imon == 1)
    {
        /* If imon=1, get monitoring information using
        nag_real_symm_sparse_eigensystem_monit (f12fec). */
        nag_real_symm_sparse_eigensystem_monit(&niter, &nconv, eigv, eigest,
        icomm, comm);
        /* Compute 2-norm of Ritz estimates using
        nag_dge_norm (f16rac). */
        nag_dge_norm(Nag_ColMajor, Nag_FrobeniusNorm, nev, 1, eigv, nev,
        &estnrm, &fail);
        printf("Iteration %3"NAG_IFMT", niter);
        printf(" No. converged = %3"NAG_IFMT", nconv);
        printf(" norm of estimates = %17.8e
", estnrm);
    }
    goto REVCOMLOOP;
}
if (fail.code == NE_NOERROR)
{
    /* Post-Process using nag_real_symm_sparse_eigensystem_sol
(f12fcc) to compute eigenvalues/vectors. */
    nag_real_symm_sparse_eigensystem_sol(&nconv, eigv, v, sigma, resid, v,
    comm, icomm, &fail);
    printf("\n The %4"NAG_IFMT" generalized Ritz values", nconv);
    for (j = 0; j <= nconv-1; ++j)
printf("%8"NAG_FMT "%5$s%12.4f\n", j+1, "", eigv[j]);
}
else
{
  printf(" Error from nag_real_symm_sparse_eigensystem_iter ", (f12fec).\n%s\n", fail.message);
  exit_status = 1;
  goto END;
}
END:
NAG_FREE(dd);
NAG_FREE(dl);
NAG_FREE(du);
NAG_FREE(du2);
NAG_FREE(comm);
NAG_FREE(eigv);
NAG_FREE(eigest);
NAG_FREE(resid);
NAG_FREE(v);
NAG_FREE(x2);
NAG_FREE(icomm);
NAG_FREE(ipiv);
return exit_status;
}
static void mv(Integer n, double *v, double *y)
{
  /* Scalars */
  double h;
  Integer j;

  /* Function Body */
  h = 1.0 / ((double)(n + 1) * 6.);
  y[0] = h*(v[0] * 4.0 + v[1]);
  for (j = 1; j <= n - 2; ++j)
  {
    y[j] = h*(v[j-1] + v[j] * 4.0 + v[j+1]);
  }
  y[n-1] = h*(v[n-2] + v[n-1] * 4.0);
  return;
} /* mv */

static void my_dgttrf(Integer n, double dl[], double d[],
   double du[], double du2[], Integer ipiv[],
   Integer *info)
{
  /* A simple C version of the Lapack routine dgttrf with argument 
   * checking removed */
  /* Scalars */
  double temp, fact;
  Integer i;
  /* Function Body */
  *info = 0;
  for (i = 0; i < n; ++i)
  {
    ipiv[i] = i;
  }
  for (i = 0; i < n - 2; ++i)
  {
    du2[i] = 0.0;
  }
  for (i = 0; i < n - 2; i++)
  {
    if (fabs(d[i]) >= fabs(dl[i]))
    {
      /* No row interchange required, eliminate dl[i]. */
      if (d[i] != 0.0)
      {
        fact = dl[i] / d[i];
      }
    }


```c
static double dl[n+1], d[n+1], du[n+1], du2[n+1], ipiv[n+1], b[n+1], y[n+1];

/* Check for a zero on the diagonal of U. */
for (i = 0; i < n; ++i)
    if (d[i] == 0.0)
        *info = i;
        goto END;

END:
return;
```

Mark 25
temp = y[i+1-ip+i] - dl[i]*y[ip];
y[i] = y[ip];
y[i+1] = temp;
} /* Solve U*x = b. */
y[n-1] = y[n-1] / d[n-1];
if (n > 1)
{
  y[n-2] = (y[n-2] - du[n-2]*y[n-1])/d[n-2];
}
for (i = n - 3; i >= 0; --i)
{
  y[i] = (y[i]-du[i]*y[i+1]-du2[i]*y[i+2])/d[i];
  return;
}

10.2 Program Data

nag_real_symm_sparse_eigensystem_option (f12fdc) Example Program Data
100 4 10 : Values for n, nev and ncv

10.3 Program Results

nag_real_symm_sparse_eigensystem_option (f12fdc) Example Program Results
The 4 generalized Ritz values closest to 0.0000 are:

1 9.8704
2 39.4912
3 88.8909
4 158.1175

11 Optional Arguments

Several optional arguments for the computational functions nag_real_symm_sparse_eigensystem_iter (f12fbc) and nag_real_symm_sparse_eigensystem_sol (f12fcc) define choices in the problem specification or the algorithm logic. In order to reduce the number of formal arguments of nag_real_symm_sparse_eigensystem_iter (f12fbc) and nag_real_symm_sparse_eigensystem_sol (f12fcc) these optional arguments have associated default values that are appropriate for most problems. Therefore, you need only specify those optional arguments whose values are to be different from their default values.

The remainder of this section can be skipped if you wish to use the default values for all optional arguments.

The following is a list of the optional arguments available. A full description of each optional argument is provided in Section 11.1.

Advisory
Both Ends
Buckling
Cayley
Defaults
Exact Shifts
Generalized
Initial Residual
Iteration Limit
Largest Algebraic
Largest Magnitude
List
Monitoring
Nolist
Print Level
Random Residual
Regular
Regular Inverse
Shifted Inverse
Smallest Algebraic
Smallest Magnitude
Standard
Supplied Shifts
Tolerance
Vectors

Optional arguments may be specified by calling nag_real_symm_sparse_eigensystem_option (f12fdc) before a call to nag_real_symm_sparse_eigensystem_iter (f12fbc), but after a call to nag_real_symm_sparse_eigensystem_init (f12fac). One call is necessary for each optional argument.

All optional arguments you do not specify are set to their default values. Optional arguments you do specify are unaltered by nag_real_symm_sparse_eigensystem_iter (f12fbc) and nag_real_symm_sparse_eigensystem_sol (f12fcc) (unless they define invalid values) and so remain in effect for subsequent calls unless you alter them.

11.1 Description of the Optional Arguments

For each option, we give a summary line, a description of the optional argument and details of constraints.

The summary line contains:
- the keywords, where the minimum abbreviation of each keyword is underlined;
- a parameter value, where the letters $a$, $i$ and $r$ denote options that take character, integer and real values respectively;
- the default value, where the symbol $\epsilon$ is a generic notation for machine precision (see nag_machine_precision (X02AJC)).

Keywords and character values are case and white space insensitive.

Optional arguments used to specify files (e.g., Advisory and Monitoring) have type Nag_FileID. This ID value must either be set to 0 (the default value) in which case there will be no output, or will be as returned by a call of nag_open_file (x04acc).

Advisory

Default = 0

(See Section 3.2.1.1 in the Essential Introduction for further information on NAG data types.)

Advisory messages are output to Nag_FileID Advisory during the solution of the problem.

Defaults

This special keyword may be used to reset all optional arguments to their default values.

Exact Shifts

Supplied Shifts

During the Lanczos iterative process, shifts are applied internally as part of the implicit restarting scheme. The shift strategy used by default and selected by the Exact Shifts is strongly recommended over the alternative Supplied Shifts (see Lehoucq et al. (1998) for details of shift strategies).

If Exact Shifts are used then these are computed internally by the algorithm in the implicit restarting scheme.
If *Supplied Shifts* are used then, during the Lanczos iterative process, you must supply shifts through array arguments of `nag_real_symm_sparse_eigensystem_iter (f12fbc)` when `nag_real_symm_sparse_eigensystem_iter (f12fbc)` returns with `irevcm = 3`; the real and imaginary parts of the shifts are supplied in `y` and `mx` respectively. This option should only be used if you are an experienced user since this requires some algorithmic knowledge and because more operations are usually required than for the implicit shift scheme. Details on the use of explicit shifts and further references on shift strategies are available in Lehoucq *et al.* (1998).

**Iteration Limit**

The limit on the number of Lanczos iterations that can be performed before `nag_real_symm_sparse_eigensystem_iter (f12fbc)` exits. If not all requested eigenvalues have converged to within `Tolerance` and the number of Lanczos iterations has reached this limit then `nag_real_symm_sparse_eigensystem_iter (f12fbc)` exits with an error; `nag_real_symm_sparse_eigensystem_sol (f12fcc)` can still be called subsequently to return the number of converged eigenvalues, the converged eigenvalues and, if requested, the corresponding eigenvectors.

**Largest Magnitude**

- **Both Ends**
- **Largest Algebraic**
- **Smallest Algebraic**
- **Smallest Magnitude**

The Lanczos iterative method converges on a number of eigenvalues with given properties. The default is for `nag_real_symm_sparse_eigensystem_iter (f12fbc)` to compute the eigenvalues of largest magnitude using **Largest Magnitude**. Alternatively, eigenvalues may be chosen which have **Largest Algebraic** part, **Smallest Magnitude**, or **Smallest Algebraic** part; or eigenvalues which are from **Both Ends** of the algebraic spectrum.

Note that these options select the eigenvalue properties for eigenvalues of OP (and B for *Generalized* problems), the linear operator determined by the computational mode and problem type.

**Nolist**

Normally each optional argument specification is not printed to **Advisory** as it is supplied. Optional argument **List** may be used to enable printing and optional argument **Nolist** may be used to suppress the printing.

**Monitoring**

(See Section 3.2.1.1 in the Essential Introduction for further information on NAG data types.)

Unless **Monitoring** is set to $-1$ (the default), monitoring information is output to **Advisory** during the solution of each problem; this may be the same as **Advisory**. The type of information produced is dependent on the value of **Print Level**, see the description of the optional argument **Print Level** in this section for details of the information produced. Please see `nag_open_file (x04acc)` to associate a file with a given **Nag_FileID**.

**Print Level**

This controls the amount of printing produced by `nag_real_symm_sparse_eigensystem_option (f12fdc)` as follows.

- **0** No output except error messages. If you want to suppress all output, set **Print Level** = 0.
- **> 0** The set of selected options.
- **2** Problem and timing statistics on final exit from `nag_real_symm_sparse_eigensystem_iter (f12fbc)`.
- **≥ 5** A single line of summary output at each Lanczos iteration.
If Monitoring is set, then at each iteration, the length and additional steps of the current Lanczos factorization and the number of converged Ritz values; during re-orthogonalization, the norm of initial/restarted starting vector; on a final Lanczos iteration, the number of update iterations taken, the number of converged eigenvalues, the converged eigenvalues and their Ritz estimates.

Problem and timing statistics on final exit from nag_real_symm_sparse_eigensystem_iter (f12fbc). If Monitoring is set, then at each iteration, the number of shifts being applied, the eigenvalues and estimates of the symmetric tridiagonal matrix $H$, the size of the Lanczos basis, the wanted Ritz values and associated Ritz estimates and the shifts applied; vector norms prior to and following re-orthogonalization.

If Monitoring is set, then on final iteration, the norm of the residual; when computing the Schur form, the eigenvalues and Ritz estimates both before and after sorting; for each iteration, the norm of residual for compressed factorization and the symmetric tridiagonal matrix $H$; during re-orthogonalization, the initial/restarted starting vector; during the Lanczos iteration loop, a restart is flagged and the number of the residual requiring iterative refinement; while applying shifts, some indices.

If Monitoring is set, then during the Lanczos iteration loop, the Lanczos vector number and norm of the current residual; while applying shifts, key measures of progress and the order of $H$; while computing eigenvalues of $H$, the last rows of the Schur and eigenvector matrices; when computing implicit shifts, the eigenvalues and Ritz estimates of $H$.

If Monitoring is set, then during Lanczos iteration loop: norms of key components and the active column of $H$, norms of residuals during iterative refinement, the final symmetric tridiagonal matrix $H$; while applying shifts: number of shifts, shift values, block indices, updated tridiagonal matrix $H$; while computing eigenvalues of $H$: the diagonals of $H$, the computed eigenvalues and Ritz estimates.

Note that setting Print Level $\geq 30$ can result in very lengthy Monitoring output.

Note that setting Print Level $\geq 30$ can result in very lengthy Monitoring output.

**Random Residual**

**Initial Residual**

To begin the Lanczos iterative process, nag_real_symm_sparse_eigensystem_iter (f12fbc) requires an initial residual vector. By default nag_real_symm_sparse_eigensystem_iter (f12fbc) provides its own random initial residual vector; this option can also be set using optional argument Random Residual. Alternatively, you can supply an initial residual vector (perhaps from a previous computation) to nag_real_symm_sparse_eigensystem_iter (f12fbc) through the array argument resid; this option can be set using optional argument Initial Residual.

**Regular**

**Regular Inverse**

**Shifted Inverse**

**Buckling**

**Cayley**

These options define the computational mode which in turn defines the form of operation $OP(x)$ to be performed when nag_real_symm_sparse_eigensystem_iter (f12fbc) returns with irevcm = $-1$ or 1 and the matrix-vector product $Bx$ when nag_real_symm_sparse_eigensystem_iter (f12fbc) returns with irevcm = 2.

Given a Standard eigenvalue problem in the form $Ax = \lambda x$ then the following modes are available with the appropriate operator $OP(x)$.

**Regular** $OP = A$

**Shifted Inverse** $OP = (A - \sigma I)^{-1}$ where $\sigma$ is real
Given a Generalized eigenvalue problem in the form $Ax = \lambda Bx$ then the following modes are available with the appropriate operator $\text{OP}(x)$.

- **Regular Inverse**: $\text{OP} = B^{-1}A$
- **Shifted Inverse**: $\text{OP} = (A - \sigma B)^{-1}B$, where $\sigma$ is real
- **Buckling**: $\text{OP} = (B - \sigma A)^{-1}A$, where $\sigma$ is real
- **Cayley**: $\text{OP} = (A - \sigma B)^{-1}(A + \sigma B)$, where $\sigma$ is real

The problem to be solved is either a standard eigenvalue problem, $Ax = \lambda x$, or a generalized eigenvalue problem, $Ax = \lambda Bx$. The optional argument **Standard** should be used when a standard eigenvalue problem is being solved and the optional argument **Generalized** should be used when a generalized eigenvalue problem is being solved.

**Tolerance**

$r$

Default $= \epsilon$

An approximate eigenvalue has deemed to have converged when the corresponding Ritz estimate is within **Tolerance** relative to the magnitude of the eigenvalue.

**Vectors**

Default $= \text{RITZ}$

The function nag_real_symm_sparse_eigensystem_sol (f12fcc) can optionally compute the Schur vectors and/or the eigenvectors corresponding to the converged eigenvalues. To turn off computation of any vectors the option **Vectors** = NONE should be set. To compute only the Schur vectors (at very little extra cost), the option **Vectors** = SCHUR should be set and these will be returned in the array argument $v$ of nag_real_symm_sparse_eigensystem_sol (f12fcc). To compute the eigenvectors (Ritz vectors) corresponding to the eigenvalue estimates, the option **Vectors** = RITZ should be set and these will be returned in the array argument $z$ of nag_real_symm_sparse_eigensystem_sol (f12fcc), if $z$ is set equal to $v$ (as in Section 10) then the Schur vectors in $v$ are overwritten by the eigenvectors computed by nag_real_symm_sparse_eigensystem_sol (f12fcc).