NAG Library Function Document

nag_opt_handle_set_nlnhess (e04rlc)

1 Purpose

nag_opt_handle_set_nlnhess (e04rlc) is a part of the NAG optimization modelling suite and defines the structure of the Hessians of the nonlinear objective and constraints, on assumption that they are present in the problem. Alternatively, it may be used to define the Hessian of the Lagrangian.

2 Specification

```
#include <nag.h>
#include <nage04.h>
```

```
void nag_opt_handle_set_nlnhess (void *handle, Integer idf, Integer nnzh,
     const Integer irowh[], const Integer icolh[], NagError *fail)
```

3 Description

After the initialization function nag_opt_handle_init (e04rac) has been called and an objective function f or nonlinear constraint function g_i has been registered with nag_opt_handle_set_nlnobj (e04rgc) and nag_opt_handle_set_nlnconstr (e04rkc), nag_opt_handle_set_nlnhess (e04rlc) can be used to define the sparsity structure of the Hessians, H, of those functions (i.e., the second partial derivatives with respect to the decision variables) or a linear combination of them, called the Lagrangian.

$$\text{Defining } \nabla^2 f \equiv \begin{pmatrix} \frac{\partial^2 f}{\partial^2 x_1} & \frac{\partial^2 f}{\partial x_2 \partial x_1} & \cdots & \frac{\partial^2 f}{\partial x_n \partial x_1} \\ \frac{\partial^2 f}{\partial x_1 \partial x_2} & \frac{\partial^2 f}{\partial^2 x_2} & \cdots & \frac{\partial^2 f}{\partial x_n \partial x_2} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{\partial^2 f}{\partial x_1 \partial x_n} & \frac{\partial^2 f}{\partial x_2 \partial x_n} & \cdots & \frac{\partial^2 f}{\partial^2 x_n} \end{pmatrix};$$

$$\text{the Hessian of the Lagrangian function} \equiv \sigma \nabla^2 f + \sum_{i=1}^{m} \lambda_i \nabla^2 g_i;$$

$$\text{the Hessian of the objective function} \equiv \nabla^2 f;$$

$$\text{the Hessian of the constraint functions} \equiv \nabla^2 g_i.$$

Each of the symmetric $n \times n$ Hessian matrices will have its own sparsity structure, in general. These structures can be given in separate nag_opt_handle_set_nlnhess (e04rlc) calls, or merged together in the Lagrangian and given in one call.

The nonzero values of the Hessians at particular points in the decision variable space will be communicated to the NLP solver by user-supplied functions (e.g., **hess** for nag_opt_handle_solve_ipopt (e04stc)).

Some NLP solvers (e.g., nag_opt_handle_solve_ipopt (e04stc)) expect either all of the Hessians (for objective and nonlinear constraints) to be supplied by the user or none and they will terminate with an error indicator if only some but not all of the Hessians have been introduced by nag_opt_handle_set_nlnhess (e04rlc).

Some NLP solvers (e.g., nag_opt_handle_solve_ipopt (e04stc), again) will automatically switch to using internal approximations for the Hessians if none have been introduced by nag_opt_handle_set_nlnhess (e04rlc). This usually results in a slower convergence (more iterations to the solution) and might even result in no solution being attainable within the ordinary tolerances.

4 References

None.

5 Arguments

1: **handle** – void * *Input*

On entry: the handle to the problem. It needs to be initialized by nag_opt_handle_init (e04rac) and **must not** be changed.

2: **idf** – Integer *Input*

On entry: specifies the quantities for which a sparsity structure is provided in **nnzh**, **irowh** and **icolh**.

idf $= -1$
The sparsity structure of the Hessian of the Lagrangian is provided.

idf $= 0$
The sparsity structure of the Hessian of the objective function is provided.

idf > 0
The sparsity structure of the Hessian of the **idf**th constraint function is provided.

The value of **idf** will also determine how an NLP solver will call the user-supplied functions that evaluate these nonzeros at particular points of the decision variable space, i.e., whether the solver will expect the nonzero values of the objective and constraint Hessians in separate calls or merged in the Lagrangian Hessian, in one call. See, for example, **hess** of nag_opt_handle_solve_ipopt (e04stc).

Constraint: $-1 \leq$ **idf** $\leq ncnln$.

Note: $ncnln$, the number of nonlinear constraints registered with the handle.

3: **nnzh** – Integer *Input*

On entry: the number of nonzero elements in the upper triangle of the matrix H.

Constraint: **nnzh** > 0.

4: **irowh**[**nnzh**] – const Integer *Input*
5: **icolh**[**nnzh**] – const Integer *Input*

On entry: arrays **irowh** and **icolh** store the nonzeros of the upper triangle of the matrix H in coordinate storage (CS) format (see Section 2.1.1 in the f11 Chapter Introduction). **irowh** specifies one-based row indices, **icolh** specifies one-based column indices and specifies the values of the nonzero elements in such a way that $h_{ij} = H[l-1]$ where $i =$ **irowh**$[l-1]$ and $j =$ **icolh**$[l-1]$, for $l = 1, 2, \ldots,$ **nnzh**. No particular order is expected, but elements should not repeat.

Constraint: $1 \leq$ **irowh**$[l-1] \leq$ **icolh**$[l-1] \leq n$, for $l = 1, 2, \ldots,$ **nnzh**.

6: **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_ALREADY_DEFINED

On entry, **idf** $= \langle value \rangle$.
The structure of the Hessian of nonlinear function linked to the given **idf** has already been defined.

The structure of the Hessian of the Lagrangian has already been defined.

The structure of the individual Hessians has already been defined, the Hessian of the Lagrangian cannot be defined.

NE_BAD_PARAM

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

NE_HANDLE

The supplied **handle** does not define a valid handle to the data structure for the NAG optimization modelling suite. It has not been initialized by nag_opt_handle_init (e04rac) or it has been corrupted.

NE_INT

On entry, **nnzh** $= \langle value \rangle$.
Constraint: **nnzh** > 0.

NE_INT_2

On entry, **idf** $= \langle value \rangle$.
Constraint: $\langle value \rangle \leq$ **idf** $\leq \langle value \rangle$.

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_INVALID_CS

On entry, $i = \langle value \rangle$, **icolh**$[i-1] = \langle value \rangle$ and $n = \langle value \rangle$.
Constraint: $1 \leq$ **icolh**$[i-1] \leq n$.

On entry, $i = \langle value \rangle$, **irowh**$[i-1] = \langle value \rangle$ and **icolh**$[i-1] = \langle value \rangle$.
Constraint: **irowh**$[i-1] \leq$ **icolh**$[i-1]$ (elements within the upper triangle).

On entry, $i = \langle value \rangle$, **irowh**$[i-1] = \langle value \rangle$ and $n = \langle value \rangle$.
Constraint: $1 \leq$ **irowh**$[i-1] \leq n$.

On entry, more than one element of structural matrix H has row index $\langle value \rangle$ and column index $\langle value \rangle$.
Constraint: each element of structural matrix H must have a unique row and column index.

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_PHASE

Neither nonlinear objective nor nonlinear constraints are present. The structure of the Hessian cannot be defined.

No nonlinear objective has been defined, its Hessian cannot be set.

The problem cannot be modified in this phase any more, the solver has already been called.

7 Accuracy

Not applicable.

8 Parallelism and Performance

nag_opt_handle_set_nlnhess (e04rlc) is not threaded in any implementation.

9 Further Comments

9.1 Additional Licensor

Parts of the code for e04rlc are distributed according to terms imposed by another licensor. Please refer to the list of Library licensors available on the NAG Website for further details.

10 Example

See Section 10 in nag_opt_handle_solve_ipopt (e04stc).