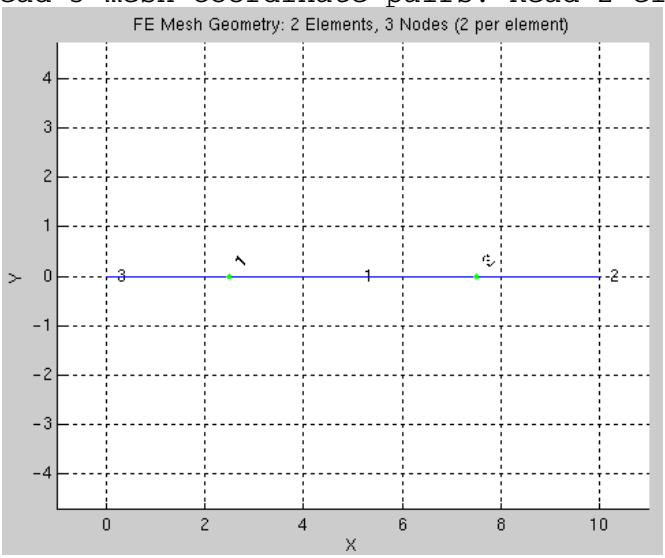
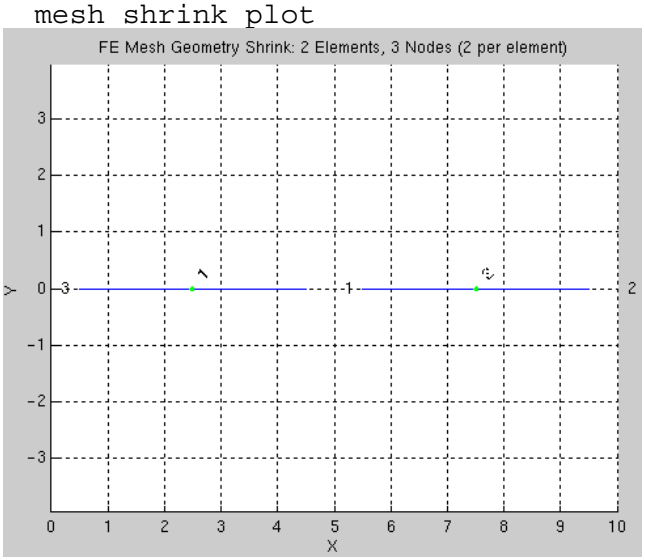
Applications of MODEL program: a large modular finite element system for static, transient, dynamic, and eigenvalue finite element studies (f90 source available for download). It was designed for general research and educational applications. Real and/or integer data can be supplied for the elements, nodes, or system. New applications require only the definition of the element matrices. Linear and mildly non-linear solutions are included. Problem data are supplied in text file test.dat, with free format control words at the beginning. A large library of existing examples is available for execution, just include the control word `example`. New applications require user source code for the element matrices, compiling and linking the new application. This example is that of a hanging bar utilizing an existing source code application (# 136) run on the Owlnet UNIX system.

```
Script started on Sun Feb 03 13:34:42 2008

% more ~mech517/public_html/Applications/136.my_el_sq_inc

! begin file 136.my_el_sq_inc
! ..............................................................
!    ***  ELEM_SQ_MATRIX PROBLEM DEPENDENT STATEMENTS FOLLOW ***
!      For required REAL (DP) :: S    (LT_FREE, LT_FREE)
!      and optional REAL (DP) :: EL_M (LT_FREE, LT_FREE)
!      and optional REAL (DP) :: C    (LT_FREE)
! ..............................................................
!  Dynamic, eigen, or static  axial or torsional response of a
!  linear bar.  Equation:-K*A U,xx + Rho*A U,tt + Q_e = 0,
!  U = displacement, K = stiffness, A = area, t = time
!  Rho = mass density, Q_e = source per unit length
!     1 *---(K_e, A_e, Rho_e, Q_e)---* 2, Element in x
  REAL(DP)  :: DL                    ! Length
  REAL(DP)  :: K_e, A_e, Rho_e, Q_e  ! properties

  DL    = ABS(COORD (2, 1) - COORD (1, 1))
  K_e   = GET_REAL_LP (1) ! modulus from real element properties
  A_e   = GET_REAL_LP (2) ! area of bar
  Rho_e = GET_REAL_LP (3) ! mass density
  Q_e   = GET_REAL_LP (4) ! source per unit volume

  S    =   K_e * A_e / DL * RESHAPE ((/1, -1, -1, 1/), (/2,2/))
  EL_M = Rho_e * A_e * DL * RESHAPE ((/2, 1, 1, 2/), (/2,2/))/6.d0
  C    = Q_e * DL * (/ 1, 1 /) * 0.5d0
! end file: 136.my_el_sq_inc

% more test.dat   # MODEL input data, UNIX Execution

title "Linear bar hanging under its own weight"
# debug_all ! large prints, if not commented out
nodes    3 ! Number of nodes in the mesh
elems    2 ! Number of elements in the system
dof      1 ! Number of unknowns per node
el_nodes 2 ! Maximum number of nodes per element
space    1 ! Solution space dimension
shape    1 ! Element shape, 1=line, 2=tri, 3=quad, 4=hex
el_real  4 ! Number of real properties per element
el_homo ! Element properties are homogeneous (input first)
list_el_react ! Compute & list element reactions
example 136 ! Application source code example number
# data_set 8  ! reader information only
remarks  6 ! Number of user remarks
quit ! keyword input, remarks follow
1 Akin lecture example: E=1, A=1, L=10, Q_e=25
2 Fixed  3           1           2 Free
3   x=0  *----(1)----*----(2)----*
4 Elem properties: K_e, A_e, Rho_e, Q_e
```

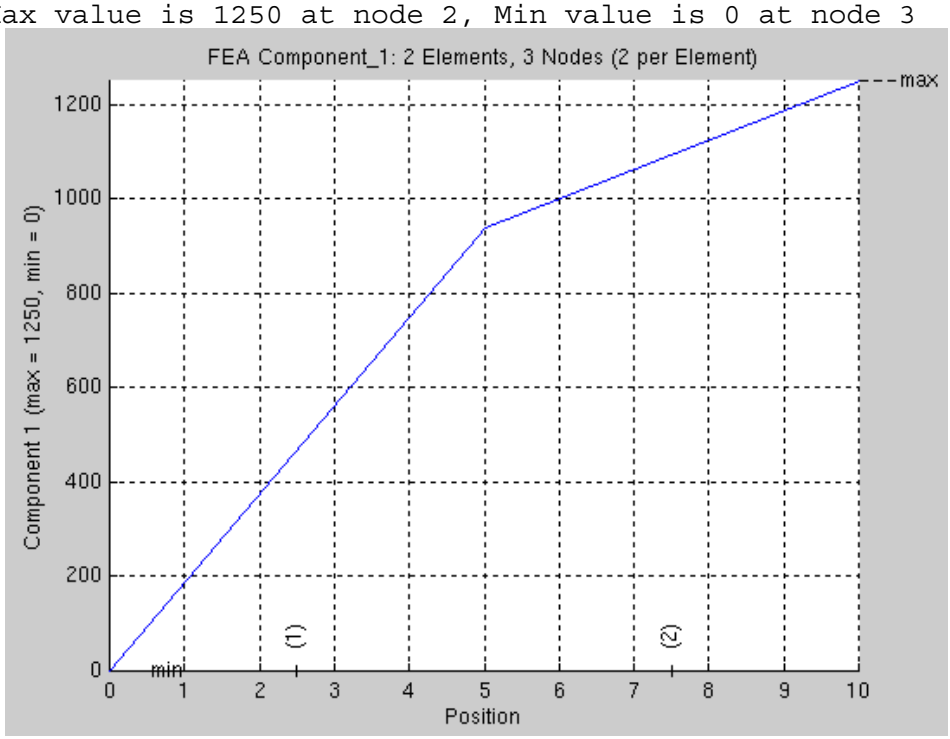
```
5 Equation: -K*A U,xx + Rho*A U,tt + Q_e = 0
6 Answer: u_2 = 312.5
 1 0 5.             ! node, bc_flag, x
 2 0 10.0           ! node, bc_flag, x
 3 1 0.0            ! node, bc_flag, x
  1    3    1     ! elem, two node conncetions
  2    1    2     ! elem, two node connections
 3  1 0.         ! node, dof, essential BC value
1 1. 1. 0. 25. ! el, E, A, Rho, Q_e (homogeneous)
%
% alias Run_Ex '~mech517/public_html/Applications/Example_Run'
%
% Run_Ex >! Output

STOP: NORMAL END OF MODEL_F90, WITH WARNINGS
%
% /usr/site/matlab-5.3/bin/matlab.sh
                                < M A T L A B >
                    Copyright 1984-1999 The MathWorks, Inc.
                          Version 5.3.0.10183 (R11)
                                Jan 21 1999

>> addpath /net/course-a/mech517/public_html/Matlab_Plots

>> mesh_plot(1,1)
Read 3 mesh coordinate pairs. Read 2 elements with 2 nodes each
```



```
>>  mesh shrink plot
```




```
>> result_1d_graph(1)
Read 3 nodal solution values  with 1 components each
Max value is 1250 at node 2, Min value is 0 at node 3
```




```
>> quit

 17263 flops.

% more output
 MODular Element Library (MODEL) 4.3.0
 J.E. Akin, Rice University, akin@rice.edu
 Beginning user keyword inputs
 WARNING, apply_key: unknown keyword list_el_react
 NOTE: USING SOURCE EXAMPLE LIBRARY NUMBER  136
 Keyword input terminated by user.
 *** DESCRIPTIONS OF EXAMPLE 136 ***
 Dynamic or Eigensolution or Statics for the axial
 or torsional response of a linear bar
 Equation: -K*A U,xx + Rho*A U,tt + Q_e = 0,
```

```
 U = displacement, K = stiffness, A = area
 Rho = mass density, Q_e = source per unit length
 1 *---(K_e, A_e, Rho_e, Q_e)---* 2, Element in x
 Prop:    1    2      3    4
 NOTE: SCP Recovery turned off since N_QP = 0
 TITLE: "Linear bar hanging under its own weight"

****  PROBLEM CLASS: (DEFAULT) VALUE ****
NUMBER OF USER REMARKS LINES ..................(0)    6
DIMENSION OF SPACE ............................(1)    1
NUMBER OF ROWS IN B MATRIX ....................(1)    1
NUMBER OF ITERATIONS TO BE RUN ................(1)    1
NUMBER OF NODAL POINTS IN SYSTEM ..............(2)    3
NUMBER OF ELEMENTS IN SYSTEM ..................(1)    2
NUMBER OF PARAMETERS PER NODE .................(1)    1
MAXIMUM NUMBER OF NODES PER ELEMENT ...........(2)    2
NUMBER OF MIXED BOUNDARY CONDITION SEGMENTS ...(0)    0
NUMBER OF NODES PER MIXED BC SEGMENT ..........(0)    0
NUMBER OF BOUNDARIES WITH GIVEN FLUX ..........(0)    0
NUMBER OF NODES ON FLUX BOUNDARY SEGMENT ......(0)    0
NUMBER OF FLUX COMPONENTS PER FLUX SEG NODE ...(0)    0
NUMBER OF DIFFERENT ELEMENT TYPES .............(1)    1
SHAPE 1=LINE 2=TRI 3=QUAD 4=HEX 5=TET 6=WEDG ..(1)    1
MAXIMUM NUMBER OF QUADRATURE POINTS ...........(0)    0

****  PROBLEM PROPERTIES: (DEFAULT) VALUE ****
NUMBER OF INTEGER PROPERTIES PER ELEMENT ......(0)    0
NUMBER OF REAL    PROPERTIES PER ELEMENT ......(0)    4
NUMBER OF INTEGER PROPERTIES PER FLUX SEGMENT..(0)    0
NUMBER OF REAL    PROPERTIES PER FLUX SEGMENT..(0)    0
NUMBER OF INTEGER MISCELLANEOUS PROPERTIES ....(0)    0
NUMBER OF REAL    MISCELLANEOUS PROPERTIES ....(0)    0
NUMBER OF INTEGER PROPERTIES PER MIXED BC .....(0)    0
NUMBER OF REAL    PROPERTIES PER MIXED BC .....(0)    0
NUMBER OF INTEGER PROPERTIES PER NODE .........(0)    0
NUMBER OF REAL    PROPERTIES PER NODE .........(0)    0
NUMBER OF MATERIAL PROPERTY SETS ..............(0)    0
NUMBER OF REAL    PROPERTIES PER MATERIAL SET..(0)    0

****  OPTIONS: (DEFAULT) VALUE ****
AXISYMMETRIC DOMAIN:          0=FALSE, 1=TRUE ..(0)    0
INITIAL FORCING VECTOR:       0=OMIT,  1=READ ..(0)    0
NULL ELEM SOURCE VECTORS:     0=FALSE, 1=TRUE ..(0)    0
UNSYMMETRIC MATRIX MODE:      0=FALSE, 1=TRUE ..(0)    0
HOMOGENEOUS ELEM PROPERTIES:  0=FALSE, 1=TRUE ..(0)    1
HOMOGENEOUS NODE PROPERTIES:  0=FALSE, 1=TRUE ..(0)    0
LIST RESULTS BY ELEMS:        0=FALSE, 1=TRUE ..(0)    0
LIST RESULTS BY NODES:        0=FALSE, 1=TRUE ..(0)    1
LIST ELEMENT REACTIONS:       0=OMIT,  1=LIST ..(0)    0
USE EXACT BC IN FE SOLUTION:  0=FALSE, 1=TRUE ..(0)    0
USE & LIST EXACT FLUXES:      0=FALSE, 1=TRUE ..(0)    0
USE & LIST EXACT SOLUTION:    0=FALSE, 1=TRUE ..(0)    0
USER POST_PROCESSING UNIT FLAG_1, ACTIVE > 0 ..(0)    0
USER POST_PROCESSING UNIT FLAG_2, ACTIVE > 0 ..(0)    0

****  SUMMARY:  (DEFAULT) VALUE ****
NUMBER OF D.O.F. FOR ELEMENT ..................(2)    2
NUMBER OF D.O.F. ON MIXED BC SEGMENT ..........(0)    0
NUMBER OF D.O.F. ON FLUX SEGMENT ..............(0)    0
NUMBER OF D.O.F. IN TOTAL SYSTEM ..............(2)    3
```

```
 THE NEXT  6  LINES ARE USER REMARKS
 1 1 Akin lecture example: E=1, A=1, L=10, Q_e=25
 2 2 Fixed  3           1           2 Free
 3 3   x=0  *----(1)----*----(2)----*
 4 4 Elem properties: K_e, A_e, Rho_e, Q_e
 5 5 Equation: -K*A U,xx + Rho*A U,tt + Q_e = 0
 6 6 Answer: u_2 = 312.5

*** NODAL POINT DATA ***
   NODE, BC_FLAG, X-Coord,
      1  0    5.0000
      2  0   10.0000
      3  1    0.0000

***  NODAL PARAMETER CONSTRAINT LIST  ***
TYPE      EQUATIONS
   1         1

*** ELEMENT CONNECTIVITY DATA ***
ELEMENT,  2 NODAL INCIDENCES.
      1     3     1
      2     1     2

*** CONSTRAINT EQUATION DATA ***
CONSTRAINT TYPE_ONE: (PAR_1 @ NODE_1) =  A_1.
EQ. NO.   NODE_1   PAR_1          A_1
      1      3      1   0.00000E+00

***  ELEMENT  PROPERTIES   ***
ELEMENT,  4 PROPERTY & REAL_VALUE PAIRS
     1  1  1.00000E+00  2  1.00000E+00
        3  0.00000E+00  4  2.50000E+01
END REAL PROPERTIES OF ELEMENTS

*** INPUT SOURCE RESULTANTS ***
ITEM       SUM           POSITIVE      NEGATIVE
    1    2.5000E+02    2.5000E+02    0.0000E+00

*** REACTION RECOVERY ***
   NODE, PARAMETER,     REACTION, EQUATION
      3,  DOF_1,      -2.5000E+02     3
REACTION RESULTANTS
PARAMETER,    SUM          POSITIVE     NEGATIVE
 DOF_1,     -2.5000E+02   0.0000E+00  -2.5000E+02

*** EXTREME VALUES OF THE NODAL PARAMETERS ***
PARAMETER         MAXIMUM,   NODE      MINIMUM,   NODE
 DOF_1,        1.2500E+03,      2   0.0000E+00,      3

***  OUTPUT OF RESULTS IN NODAL ORDER  ***
    NODE,  X-Coord,    DOF_1,
       1  5.0000E+00  9.3750E+02
       2  1.0000E+01  1.2500E+03
       3  0.0000E+00  0.0000E+00

 STATIC_MODEL GAVE  1  WARNINGS
% ^D
script done on Sun Feb 03 13:48:04 2008
```

Next the stepped hanging bar supported in the middle is run to compare with the Matlab script. Several changes to the data file are required.

```
Script started on Sun Feb 03 14:36:58 2008

% more test.dat
title "Stepped bar under its own weight supported at middle"
# debug_all ! large prints, if not commented out
nodes    3 ! Number of nodes in the mesh
elems    2 ! Number of elements in the system
dof      1 ! Number of unknowns per node
el_nodes 2 ! Maximum number of nodes per element
space    1 ! Solution space dimension
shape    1 ! Element shape, 1=line, 2=tri, 3=quad, 4=hex
el_real  4 ! Number of real properties per element
# el_homo ! Element properties are homogeneous (input first)
example 136 ! Application source code example number
remarks  5 ! Number of user remarks
quit ! keyword input, remarks follow
1 Akin Matlab lecture example: E=1, A_1=2, A_2=1, L=10, Q_e=25
2        1           2 Fixed     3
3   x=0  *----(1)----*----(2)----*
4 Elem properties: K_e, A_e, Rho_e, Q_e
5 Equation: -K*A U,xx + Rho*A U,tt + Q_e = 0
 1 0 0.            ! node, bc_flag, x
 2 1 5.0           ! node, bc_flag, x
 3 0 10.0          ! node, bc_flag, x
  1    1    2    ! elem, two node conncetions
  2    2    3    ! elem, two node connections
 2  1 0.        ! node, dof, essential BC value
1 1. 2. 0. 25 ! elem E, A, rho, Q_e
2 1. 1. 0. 25 ! elem E, A, rho, Q_e
%

% alias Run_Ex '/net/course-a/mech517/public_html/Applications/Example_Run'

% Run_Ex >! output
STOP: NORMAL END OF MODEL_F90 (NO WARNINGS)

% more output

 MODular Element Library (MODEL) 4.3.0
 J.E. Akin, Rice University, akin@rice.edu

 TITLE: "Stepped bar under its own weight supported at middle"

*** NODAL POINT DATA ***
   NODE, BC_FLAG, X-Coord,
      1  0    0.0000
      2  1    5.0000
      3  0   10.0000

*** ELEMENT CONNECTIVITY DATA ***
ELEMENT,  2 NODAL INCIDENCES.
      1     1     2
      2     2     3

*** CONSTRAINT EQUATION DATA ***
CONSTRAINT TYPE_ONE: (PAR_1 @ NODE_1) =  A_1.
EQ. NO.   NODE_1   PAR_1          A_1
      1      2      1   0.00000E+00

***  ELEMENT  PROPERTIES   ***
ELEMENT,  4 PROPERTY & REAL_VALUE PAIRS
```

```
     1  1 1.000E+0  2  2.000E+0  3  0.000E+0  4  2.500E+1
     2  1 1.000E+0  2  1.000E+0  3  0.000E+0  4  2.500E+1
END REAL PROPERTIES OF ELEMENTS

*** INPUT SOURCE RESULTANTS ***
ITEM       SUM           POSITIVE      NEGATIVE
    1    2.5000E+02    2.5000E+02    0.0000E+00

*** REACTION RECOVERY ***
   NODE, PARAMETER,     REACTION, EQUATION
      2,  DOF_1,      -2.5000E+02     2
REACTION RESULTANTS
PARAMETER,    SUM          POSITIVE     NEGATIVE
 DOF_1,     -2.5000E+02   0.0000E+00  -2.5000E+02

*** EXTREME VALUES OF THE NODAL PARAMETERS ***
PARAMETER         MAXIMUM,   NODE      MINIMUM,   NODE
 DOF_1,        3.1250E+02,      3   0.0000E+00,      2

***  OUTPUT OF RESULTS IN NODAL ORDER  ***
    NODE,  X-Coord,    DOF_1,
       1  0.0000E+00  1.5625E+02
       2  5.0000E+00  0.0000E+00
       3  1.0000E+01  3.1250E+02

 NORMAL END OF MODEL_F90 (NO WARNINGS)
% ^D
script done on Sun Feb 03 14:38:21 2008
```