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ON THE APPEND AND CONTINUE FEATURES IN NASTRAN

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SUMMARY

This paper describes two very important and useful features available in Level 17.0 version of NASTRAN. The first one is the APPEND feature which is applicable in the case of real eigenvalue analysis. This feature permits the addition of new eigenvalues and eigenvectors to those already computed in a previously checkpointed run without re-executing the entire problem. The second feature is the CONTINUE feature which is applicable in the case of transient analysis of coupled equations. This feature enables the integration of coupled equations to be continued beyond the last (or from any earlier intermediate) output time for which the solution was obtained in a previously checkpointed run (without re-executing the entire problem). The paper illustrates the use of these two features by suitable examples.

INTRODUCTION

The checkpoint/restart feature available in NASTRAN is a very useful capability that permits the restarting of previously checkpointed runs without re-executing the entire problem. The modules that need to be executed on restart are determined by the nature of modifications made to the checkpointed data by the user upon restart. Depending on these modifications, four types of restarts may be identified. These are the Unmodified Restart, Modified Restart, Rigid Format Switch and Pseudo Modified Restart. The details of these restarts are discussed in Reference 1. It is to be noted, however, that the user does not explicitly specify the type of restart. It is implied and automatically determined by the changes made to the NASTRAN data deck upon restart.

It is important to note that a restart only determines the modules that need to be executed during the current run. A restart does not, in general, affect the logic of execution within a given module. There are, however, two important exceptions to this. These are the APPEND and CONTINUE features available in Level 17.0 version of NASTRAN. These are discussed in detail in the following sections.

THE APPEND FEATURE

In real eigenvalue analysis, it is frequently necessary to add new eigenvalues and eigenvectors to those already computed in a previous run. The APPEND feature available in Level 17.0 version of NASTRAN makes it possible to do this without re-executing the entire problem. It is available only when using the Inverse Power, Determinant and Tridiagonal Reduction (FEER) methods of eigenvalue extraction in Rigid Formats 3, 10, 11, 12, 13 and 15 (Displacement approach) and in Rigids Formats 10 and 11 (Aeroelastic approach). This feature is particularly valuable in the case of large order eigenvalue problems.

In order to use the APPEND feature, the user first requests a checkpoint of an eigenvalue problem employing one of the three above-mentioned methods of eigenvalue extraction. This run can terminate for any reason so long as the READ (Real Eigenvalue Analysis-Displacement approach) module finds at least one eigenvalue and one eigenvector and the LAMA (eigenvalue) and PHIA (eigenvector) files are successfully checkpointed. The READ module also sets the parameter NEIGV to be equal to the number of eigenvalues and eigenvectors found on this checkpoint run.

The user then restarts and activates the APPEND feature by changing either the METHØD card in the Case Control Deck and/or the EIGR card in the Bulk Data Deck so as to force the re-execution of the READ module. The method of eigenvalue extraction used in the restart need <u>not</u> be the same as that used in the checkpoint run, but the structural model and the constraint data <u>must</u> be the same. Also, the user must ensure that the range of eigenvalues specified on the EIGR Bulk Data card for the restart does <u>not</u> include the eigenvalues that have previously been found and checkpointed. It is left to the user to satisfy this requirement. The program does not check for this condition.

The APPEND feature causes the READ module to retrieve the eigenvalues and eigenvectors from the previously checkpointed LAMA and PHIA files, respectively, (this retrieval is done in subroutine READ7 within the READ module; the number of eigenvalues and eigenvectors retrieved is indicated by a user information message) and to subsequently combine them with the newly computed results. This is shown schematically by the flow diagram in Figure 1. The eigenvalues and eigenvectors output by the restart <u>include</u> those previously checkpointed. Also, the resulting eigenvectors are normalized according to the method of normalization specified in the restart.

In certain cases of restart, the user may not be interested in retrieving all the NEIGV eigenvalues and eigenvectors found on a checkpoint run. In such cases, the user may retrieve only the first n (n < NEIGV) eigenvalues and eigenvectors from the LAMA and PHIA files, respectively, by resetting the parameter NEIGV in the restart to be equal to n (this capability is not available in Level 17.0, but will be in Level 17.5.) by means of a PARAM statement just before the READ module in the DMAP sequence. This is done by means of a DMAP alter in the Executive Control Deck of the restart.

THE CONTINUE FEATURE

In transient analysis, it is frequently necessary to continue the integration of the coupled equations beyond the last (or from any earlier intermediate) output time for which the solution was obtained in a previous run. Thus, the initial time for the new run is to be a specified output time of the previous run. Also, the displacements, velocities and accelerations corresponding to the specified output time of the previous run are to be used as the initial conditions for the new run. The CONTINUE feature available in Level 17.0 version of NASTRAN makes it possible to do this without re-executing the entire problem. It is available in both Rigid Formats 9 and 12 (Displacement approach). This feature can be particularly valuable in the case of large order transient analysis problems involving extended integrations.

In order to use the CONTINUE feature, the user first requests a checkpoint of a coupled transient analysis problem in the normal manner. This run can terminate for any reason so long as the TRD (Transient Analysis-Displacement approach) module computes the solution for at least one output time and the UDVT (displacement-velocity-acceleration) file is successfully checkpointed. The TØL (list of output times) file would have been previously checkpointed subsequent to the execution of the TRLG (Transient Load Generator) module. The TRD module also sets the parameter NCØL to be equal to the number of output time steps (which is also equal to one-third the number of columns in the UDVT matrix) in the checkpoint run.

The user then restarts and activates the CONTINUE feature by changing any one or more of several cards either in the Case Control Deck (DLØAD, NØNLINEAR, TSTEP cards) and/or in the Bulk Data Deck (TSTEP, DAREA, DLØAD, FØRCE, etc.) that define either the dynamic loading and/or the time step selection. This forces the re-execution of both the TRLG and TRD modules. The dynamic loading and/or the time step selection in the restart need not be the same as that used in the checkpoint run, but the structural model and the constraint data must be the same.

The CONTINUE feature causes the integration of the coupled equations to continue from a specific initial time. For normal restarts (in which the checkpointed value of the parameter NCØL is automatically used), this initial time is the last output time of the checkpoint run. However, in certain cases, the user may wish to restart the integration from an intermediate (rather than from the last) output time of the checkpoint run. In such cases, the user should reset the parameter NCØL to correspond to the desired intermediate output time by means of a PARAM statement just before the TRLG module in the DMAP sequence. This is done by means of a DMAP alter in the Executive Control Deck of the restart.

The output of the restart does not include the solutions of the checkpoint run, but only those solutions that are computed by the restart. Also, any initial conditions specified in the restart data are ignored since the solution is continued by using the displacements, velocities and accelerations corresponding to the specified output time of the checkpoint run as initial conditions for the restart.

The first displacement $\{u_1\}$ of the restart (or CONTINUEd run) is given by

$$[D]\{u_1\} = \frac{1}{3}\{P_{-1} + P_0 + P_1\} + \{N_0\} + [C]\{u_n\} + [E]\{u_{-1}\} \quad , \qquad (1)$$

where the matrices [D], [C] and [E] are given by

$$[D] = \left(\frac{1}{\Delta t^2}[M] + \frac{1}{2\Delta t}[B] + \frac{1}{3}[K]\right) \quad , \tag{2}$$

$$[C] = \left(\frac{2}{\Delta t^2}[M] - \frac{1}{3}[K]\right) \quad , \tag{3}$$

and

$$[E] = \left[\frac{-1}{\Delta t^2}[M] + \frac{1}{2\Delta t}[B] - \frac{1}{3}[K]\right] \quad , \tag{4}$$

and

$$\{P_0\} = [K]\{u_n\} + [B]\{\dot{u}_n\} + [M]\{\ddot{u}_n\} \quad , \tag{5}$$

$$\{u_{-1}\} = \{u_n\} - \Delta t\,\{\dot{u}_n\} + \frac{\Delta t^2}{2}\{\ddot{u}_n\} \quad , \tag{6}$$

$$\{\dot{u}_{-1}\} = \{\dot{u}_n\} - \{\ddot{u}_n\}\,\Delta t \quad , \tag{7}$$

$$\{P_{-1}\} = [M]\{\ddot{u}_n\} + [B]\{\dot{u}_{-1}\} + [K]\{u_{-1}\} \quad . \tag{8}$$

In the above equations, [M], [B] and [K] are the mass, damping and stiffness matrices, respectively; $\{u_n\}$, $\{\dot{u}_n\}$ and $\{\ddot{u}_n\}$ are the displacements, velocities and accelerations, respectively, at the specified output time t_n of the checkpoint run, and Δt is the initial time step for the restart. $\{P_1\}$ is the load at time $t = t_n + \Delta t$ and $\{N_0\}$ is the initial non-linear load.

The assumptions represented by Equations (6) through (8) introduce errors in the restart. These inherent errors may be minimized by selecting the initial time step in the restart to be the same as the time step used in the checkpoint run just before the restart.

EXAMPLES

In order to illustrate the use of the APPEND and CONTINUE features discussed above, two examples were selected. Example 1 is the analysis of the transverse vibrations of a 10-cell beam. The finite element model used is shown in Figure 2. Example 2 is the transient analysis of a 1000-cell string (travelling wave problem). This is the same as NASTRAN Demonstration Problem No. 9-2-1 (Reference 2). The finite element model used is shown in Figure 3. Both these problems were run on the CDC CYBER computer using a post-Level 17.0 version of NASTRAN.

Discussion of Example 1

All the twenty (20) natural frequencies of the model of Example 1 were first computed. These are listed in Table 1 to facilitate comparison with subsequent results. In order to illustrate the use of the APPEND feature, a checkpoint run was then made using the Inverse Power method and the first eight modes were computed. These are presented in Table 2. Using the results of this checkpoint run, restarts were then made under various conditions using different extraction methods. The results obtained are presented in Table 3. As can be seen, all these restarts involve the retrieval of the eight modes of the checkpoint run of Table 2.

Discussion of Example 2

A transient analysis of the model of Example 2 was first made using twenty (20) time steps. (All runs for this example were made on Rigid Format 9 using time steps of 0.0005 seconds.) The displacements for point 10 are listed in Table 4 to facilitate comparison with subsequent results. In order to illustrate the CONTINUE feature, a checkpoint run was then made using only ten (10) time steps. The displacements for point 10 obtained in this run are presented in Table 5. As can be seen, these results are merely a subset of those in Table 4. The integration of Table 5 was then CONTINUEd for ten (10) more time steps by restarting from the last output time in Table 5 (0.005 second). The results are presented in Table 6. In order to illustrate the resetting of the parameter NCØL, an additional restart was made by changing the value of NCØL to 6 (from its original value of 11) and the integration of Table 5 was CONTINUEd for fifteen (15) more time steps. This thus involved starting from an initial time of 0.0025 second. The results of this run are shown in Table 7. A comparison of the results of Tables 6 and 7 with the corresponding results in Table 4 reveals the inherent errors caused by the CONTINUE feature.

SUMMARY AND CONCLUSIONS

Two very important and useful features available in Level 17.0 version of NASTRAN have been described. The first one is the APPEND feature which is applicable in the case of real eigenvalue analysis. This feature permits the addition of new eigenvalues and eigenvectors to those already computed in a previously checkpointed run without re-executing the entire problem. The second feature is the CONTINUE feature which is applicable in the case of transient analysis of coupled equations. This enables the integration of coupled equations to be continued beyond the last (or from any earlier intermediate) output time for which the solution was obtained in a previously checkpointed run (without re-executing the entire problem). The use of these two features has been illustrated by means of two suitable examples.

REFERENCES

1. The NASTRAN User's Manual, (Level 16.0), NASA SP-222(03), March 1976.

2. The NASTRAN Demonstration Problem Manual, (Level 16.0), NASA SP-224(03), March 1976.

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Table 1. Results for Example 1
(using Givens method)

Mode no.	Natural frequency (Hz)
1	1.591560E-02
2	6.366879E-02
3	1.433160E-01
4	2.550698E-01
5	3.994578E-01
6	5.775080E-01
7	7.909161E-01
8	1.042057E+00
9	1.332764E+00
10	1.766489E+00
11	2.091890E+00
12	2.549921E+00
13	3.086530E+00
14	3.712652E+00
15	4.440216E+00
16	5.273030E+00
17	6.187597E+00
18	7.097013E+00
19	7.814544E+00
20	8.095071E+00

Table 2. Results of Checkpoint Run of Example 1
(using Inverse Power method)

Mode no. in Table 1	Natural frequency (Hz)
1	1.591560E-02
2	6.366879E-02
3	1.433160E-01
4	2.550698E-01
5	3.994578E-01
6	5.775080E-01
7	7.909161E-01
8	1.042057E+00
Eigenvalue extraction data	
F1 = 0.0 Hz	NE = 8
F2 = 1.2 Hz	ND = 8

Table 3. *Results of Restart Runs of Example 1 Using Checkpoint Run of Table 2*

Inverse Power method		Determinant method		Tridiagonal Reduction (FEER) method		Remarks
Mode no. in Table 1	Natural frequency (Hz)	Mode no. in Table 1	Natural frequency (Hz)	Mode no. in Table 1	Natural frequency (Hz)	
1	1.591560E-02	1	1.591560E-02	1	1.591560E-02	Results retrieved from the checkpoint run of Table 2
2	6.366879E-02	2	6.366879E-02	2	6.366879E-02	
3	1.433160E-01	3	1.433160E-01	3	1.433160E-01	
4	2.550698E-01	4	2.550698E-01	4	2.550698E-01	
5	3.994578E-01	5	3.994578E-01	5	3.994578E-01	
6	5.775080E-01	6	5.775080E-01	6	5.775080E-01	
7	7.909161E-01	7	7.909161E-01	7	7.9091[illegible]1E-01	
8	1.042057E+00	8	1.042057E+00	8	1.042057E+00	
12	2.549921E+00	10	1.766489E+00	9	1.332764E+00	Results computed by the method selected
13	3.086530E+00	11	2.091890E+00	10	1.766489E+00	
14	3.712652E+00	12	2.549921E+00	11	2.091890E+00	
15	4.440216E+00	13	3.086530E+00	12	2.549921E+00	
16	5.273030E+00	14	3.712652E+00	13	3.086530E+00	
17	6.187597E+00	15	4.440216E+00	14	3.712652E+00	
18	7.097013E+00			15	4.440216E+00	
19	7.814544E+00			16	5.273030E+00	
				17	6.187597E+00	
				18	7.097013E+00	
				19	7.814544E+00	
				20	8.095071E+00	
Eigenvalue extraction data						
F1 = 3.0 Hz	NE = 8	F1 = 2.0 Hz	NE = 6	F1 = 5.0 Hz	ND = 11	
F2 = 9.0 Hz	ND = 16	F2 = 6.0 Hz	ND = 14			

Table 4. Results for Example 2

Time (sec.)	Time step no.	Displacement of Point 10
0.0	1	1.800000E+00
0.0005	2	1.797927E+00
0.0010	3	1.787102E+00
0.0015	4	1.755303E+00
0.0020	5	1.690605E+00
0.0025	6	1.589987E+00
0.0030	7	1.464497E+00
0.0035	8	1.334881E+00
0.0040	9	1.220342E+00
0.0045	10	1.127921E+00
0.0050	11	1.049639E+00
0.0055	12	9.691645E-01
0.0060	13	8.733444E-01
0.0065	14	7.607323E-01
0.0070	15	6.416159E-01
0.0075	16	5.300468E-01
0.0080	17	4.338371E-01
0.0085	18	3.495874E-01
0.0090	19	2.659541E-01
0.0095	20	1.724413E-01
0.0100	21	6.725148E-02

Table 5. Results of Checkpoint Run of Example 2

Time (sec.)	Time step no. of Table 4	Displacement of Point 10
0.0	1	1.800000E+00
0.0005	2	1.797927E+00
0.0010	3	1.787102E+00
0.0015	4	1.755303E+00
0.0020	5	1.690605E+00
0.0025	6	1.589987E+00
0.0030	7	1.464497E+00
0.0035	8	1.334881E+00
0.0040	9	1.220342E+00
0.00[illegible]	10	1.127921E+00
0.00[illegible]	11	1.049639E+00

Table 6. Results of Restart Run of Example 2 Using Checkpoint Run of Table 5

Time (sec.)	Time step no. of Table 4	Displacement of Point 10
0.0050	11	1.049639E+00
0.0055	12	9.644270E-01
0.0060	13	8.673986E-01
0.0065	14	7.575025E-01
0.0070	15	6.432689E-01
0.0075	16	5.357538E-01
0.0080	17	4.405755E-01
0.0085	18	3.543471E-01
0.0090	19	2.677839E-01
0.0095	20	1.729413E-01
0.0100	21	6.924284E-02

Table 7. Results of Restart Run of Example 2 Using Checkpoint Run of Table 5 and With Parameter NCØL Reset to 6

Time (sec.)	Time step no. of Table 4	Displacement of Point 10
0.0025	6	1.589987E+00
0.0030	7	1.470335E+00
0.0035	8	1.344651E+00
0.0040	9	1.229273E+00
0.0045	10	1.132560E+00
0.0050	11	1.049933E+00
0.0055	12	9.681384E-01
0.0060	13	8.746610E-01
0.0065	14	7.659208E-01
0.0070	15	6.489350E-01
0.0075	16	5.357538E-01
0.0080	17	4.349093E-01
0.0085	18	3.459289E-01
0.0090	19	2.605215E-01
0.0095	20	1.692299E-01
0.0100	21	6.859591E-02

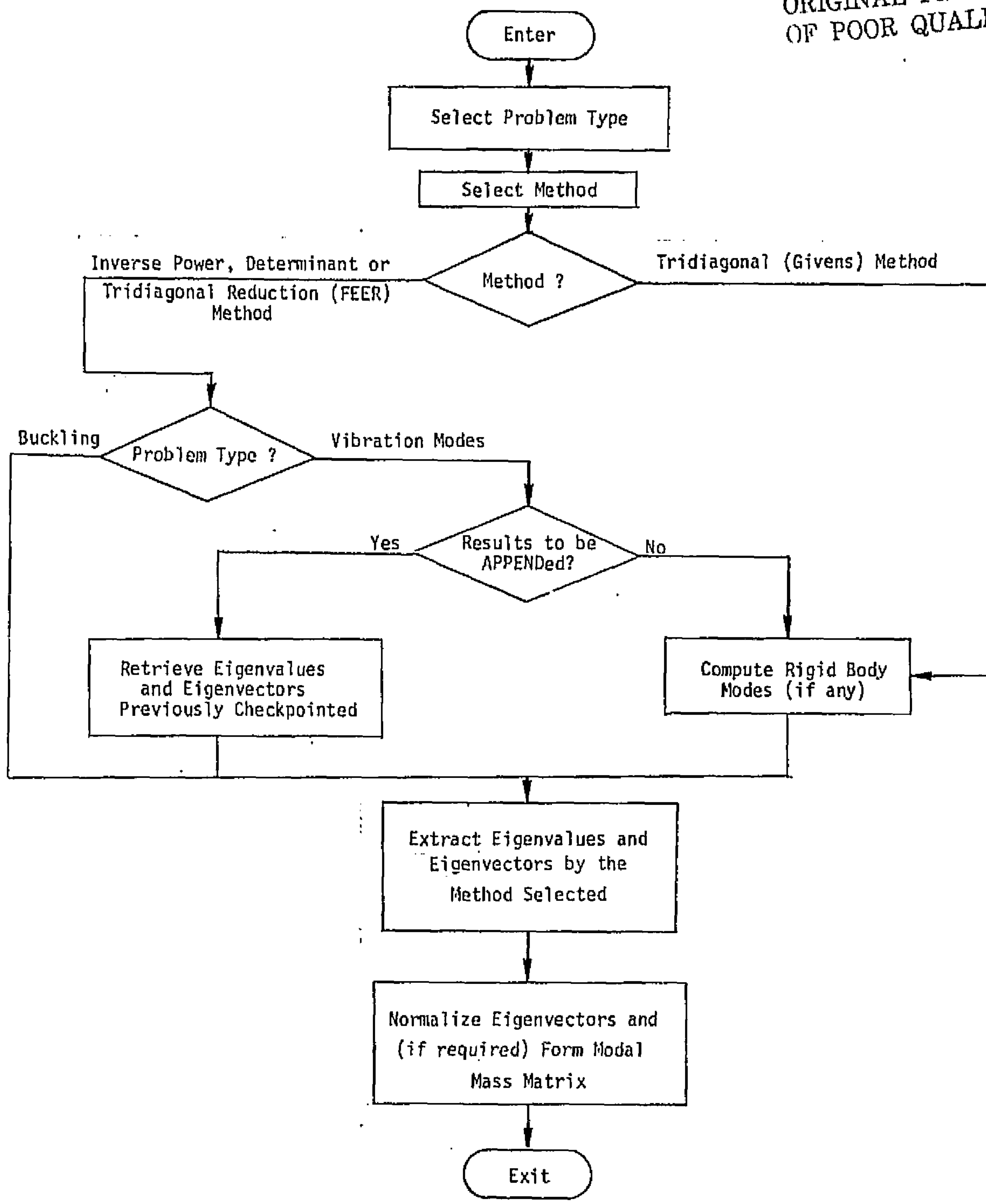
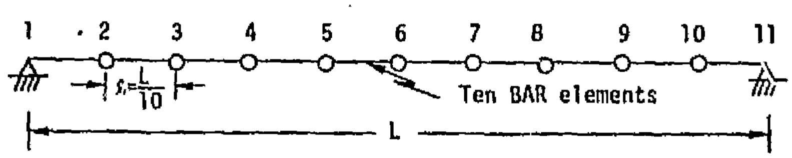


Figure 1. Flow Diagram for the Real Eigenvalue Analysis Module, READ.



Parameters:

Length of each BAR element = $\ell = \frac{L}{10}$ = 1000.0 in. (25.4 m)

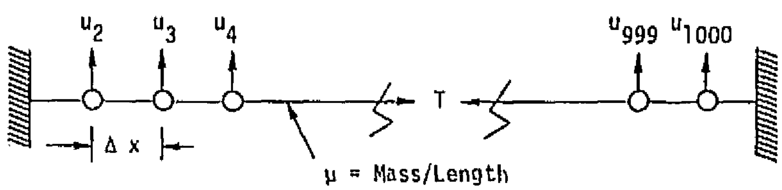
Young's modulus = Shear modulus = 1.0×10^7 psi (6.89477×10^{10} N/m^2)

Mass density = 0.9869604 lb.-sec^2/in.^{4} (1.05475×10^7 Kg/m^3)

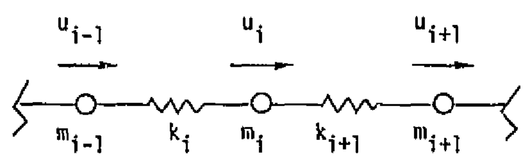
Area of cross section of each BAR element = 9.869604 in.^{2}
= 6.36747×10^{-3} m^2

Area moments of inertia = 1.0×10^6 in.^{4}
= 0.41623 m^4

Figure 2. Representation of 10-Cell Beam of Example 1



1000-Cell String



Finite Element Model

Parameters:

$k_i = \frac{T}{\Delta x} = 10^7$ (stiffness units) for all i

$m_i = \mu \Delta x = 10$ (mass units) for all i

Loading:

The initial displacements are given by:

$u_i = 0.2\,(i-1)$ for $2 \leq i \leq 11$

$u_i = 0.2\,(21-i)$ for $11 \leq i \leq 21$

and

$u_i = 0.0$ for $i \geq 21$

Figure 3. Representation of 1000-Cell String of Example 2