AC 2007-975: ANIMATION SOFTWARE FOR UPPER-LEVEL DYNAMICS AND VIBRATIONS COURSES

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Animation Software for Upper-Level Dynamics and Vibrations Courses

Abstract

Four software modules for upper-undergraduate/first-graduate-level dynamics and vibrations courses are presented. The modules treat (1) single-degree-of-freedom spring-mass-damper systems, (2) up to three-degree-of-freedom systems, (3) transverse vibration of uniform beams, and (4) three-dimensional rigid-body attitude dynamics. The first three modules use the Visual Basic platform and have been used as supplementary material in a senior-level vibrations course. The fourth module uses Matlab. Student feedback is included.

Introduction

The advent of student-owned personal computers in the early 1980's sparked an interest in motion simulation software. The simple notion is that if students are able to see an animation of the systems that they are studying, especially for their choice of conditions, then they are much more likely to understand the material. A number of investigators[1-5] have worked in this area.

The history of the motion-simulation modules presented in this paper dates back to the early 1980's when personal computers were first required for undergraduate engineering students at Virginia Tech. The first efforts by the senior author toward animation of dynamic systems were DOS-based[6]. A later generation was based on the Authorware Platform[7]. The most recent efforts directed toward sophomore-level mechanics courses are written in Flash[8].

The present vibrations modules were prepared for use in the senior course in vibrations which is required as part of the B.S. in Engineering Science and Mechanics at Virginia Tech. The rigid-body module was prepared for use in any dynamics course which treats three-dimensional rigid-body kinematics and kinetics.

Description of the Software

1. Single-Degree-of-Freedom Vibrations Module

This module gives the user the ability to enter all conditions and then view the resulting motion of single-degree-of-freedom spring-mass-damper systems. Figure 1 shows the popup input menu. In the main animation mode (Figure 2), the motion is shown in near real time. As the simulation of the system occurs at the left of the screen, a time-history of the motion is generated at the lower right. Note that a scaled red arrow indicates the force magnitude and direction, and a black pointer attached to the mass serves as an indicator of the instantaneous displacement. If the system is forced, plots of the magnification factor and the phase angle, both as functions of the nondimensionalized driving frequency ratio, are shown in the upper part of the screen, with red dots indicating the present conditions. Various items of interest, such as the natural frequency, the critical damping value, the amplitude of the steady-state solution, etc., are always immediately available. In addition to a brief set of instructions on using the software, a comprehensive set of prepared tutorials with judiciously chosen conditions is available.

A second mode of use, the parameter-variation mode (Figure 3, shown larger), allows the user to continuously vary the conditions of the motion and immediately see the effects of this single
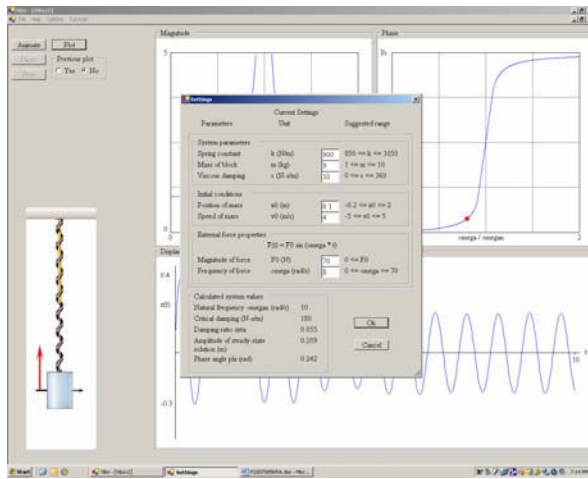

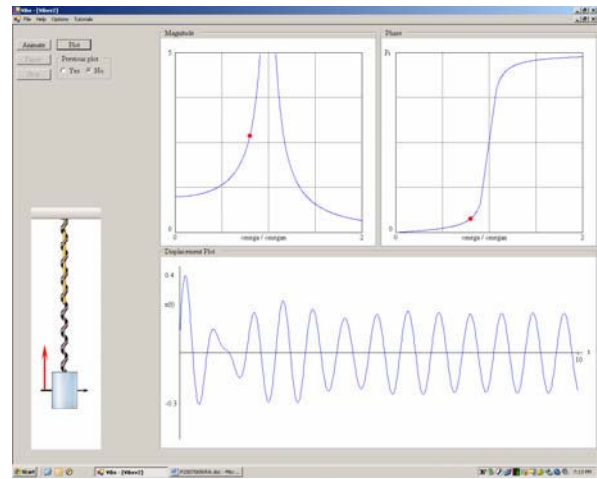Figure 1. Animation input page

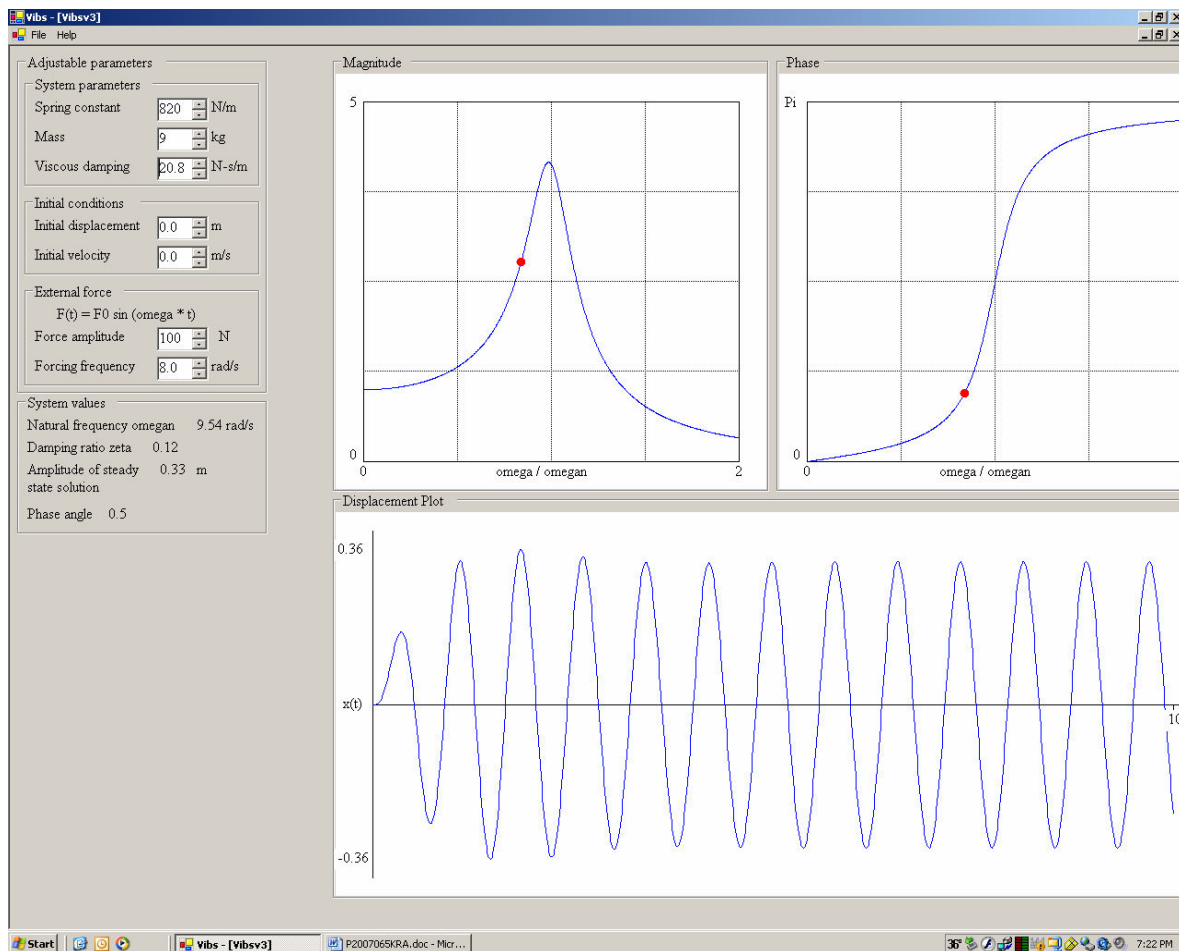Figure 2. Corresponding animation page

Figure 3. The parameter-variation mode for single-degree-of-freedom systems

variation on the plot of the time-history of the motion, as well as on the plots of the magnification factor and phase angle. As one parameter is varied, all other parameters remain constant.

2. Multi-Degree-of Freedom Vibrations Module

This module is similar to the first one except that up to three degrees of freedom (dof) are allowed, and the second mode (the parameter-variation mode) is not present. As indicated at the upper right of Figure 4, there is the option of specifying whether a bottom spring is present for the case of two degrees of freedom (this allows the demonstration of the undamped, unforced beat phenomenon shown in Figure 4).

If one specifies external forces (Figure 5), there is the opportunity to specify harmonic forces of any amplitude, frequency, and phase angle – one force for each mass. As before, a scaled red arrow attached to the mass indicates the force magnitude and direction, while a black pointer attached to the mass serves as an indicator of the instantaneous displacement.
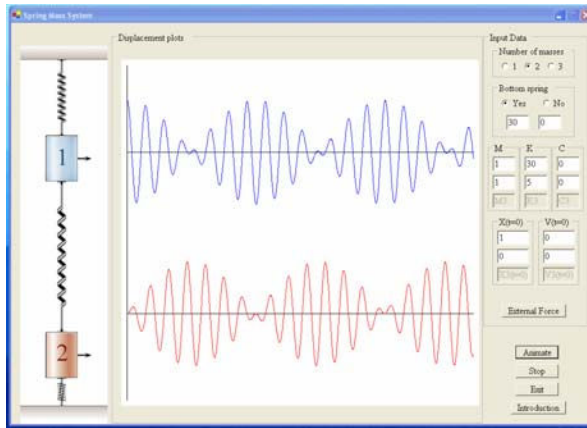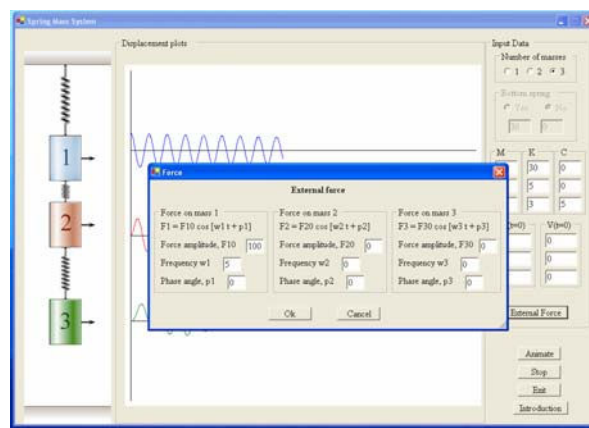

Figure 4. A 2 dof beat phenomenon

Figure 5. Specification of external forces

3. Transverse Vibration of Uniform Beams

This module allows the specification of the following classical boundary conditions for the transverse vibration of a uniform beam: free-free, fixed-free, fixed-fixed, pinned-free, fixed-pinned, and pinned-pinned. Once the user has selected the boundary conditions, any one of the first four modes of vibration may then be selected, and an animation is shown (Figure 6). A sliding control at the bottom of the screen allows the user to vary the speed of the animation as well as the maximum deflection. The natural frequency is indicated.

In addition to the classical boundary conditions listed above, the user may also choose from a free, pinned, or fixed left condition, and then specify a rigid body for the right end. In this case, the beam and end-mass properties are all selectable. See Figure 7.
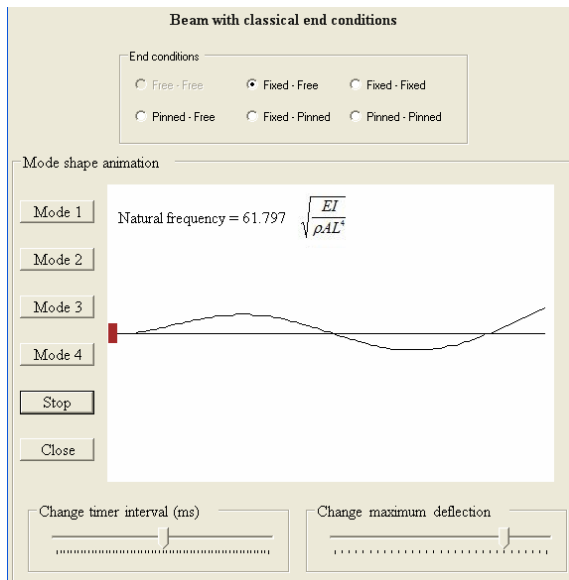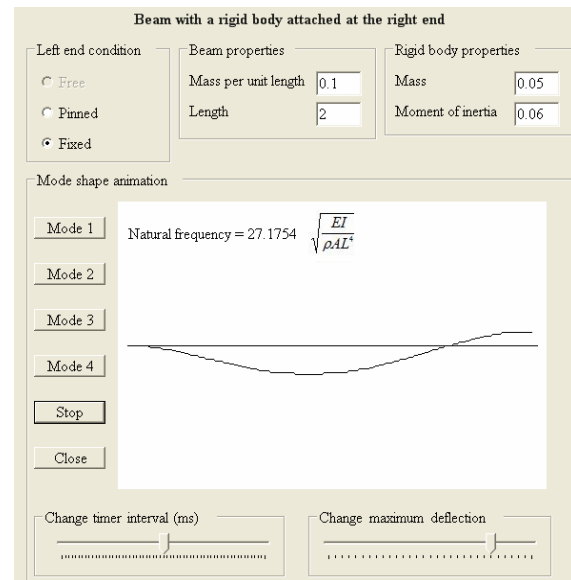
Figure 6. Transverse beam vibration

Figure 7. Beam with end mass

4. Three-Dimensional Rigid-Body Dynamics

By means of a complete graphical user interface, the user can specify any mass moments of inertia (with the result that the onscreen body is then sized accordingly), any initial orientation, any initial angular-velocity components, and any external torque history. Note that the initial orientation can be input in either Euler parameters or any of the twelve Euler-angle sequences (1-2-3, the classical 3-1-3 set, etc.). The user is then presented with an animation of the attitude motion, with freeze-action always available. Time histories of angular velocity and attitude (again, either described via Euler parameters or via any of the twelve sets of Euler angles) are available.

Figure 8, which shows the input interface, indicates the power of generality that the user possesses while using this module. Figure 9 shows a typical motion-parameter plot (in this case, 3-1-3 Euler angles) that is always available. Figure 10 shows a typical frozen animation screen. It can be seen in Figure 10 that the body-fixed axes (x-y-z) are always shown attached to the body. Also, the user has an unrestricted choice of viewpoint of the inertial X-Y-Z axes.

This module has proved extremely useful for many situations in which a physical demonstration is exceedingly difficult. For example, in a typical upper-level dynamics class, the instructor might introduce the unstable case of near-pure spin about the axis of intermediate inertia, and then spin a rubber-banded textbook (flipping it into the air) about one axis at a time in an attempt to give the students a fleeting glimpse of the behavior. This software allows for a much more relaxed and lengthy examination of this important case. The same can be said about the case of the coning motion of an axisymmetric body. Both these cases have implications in the design of spacecraft.

A useful feature of this module, especially for efficient classroom use, is the ability to store any number of simulation cases for later demonstration.
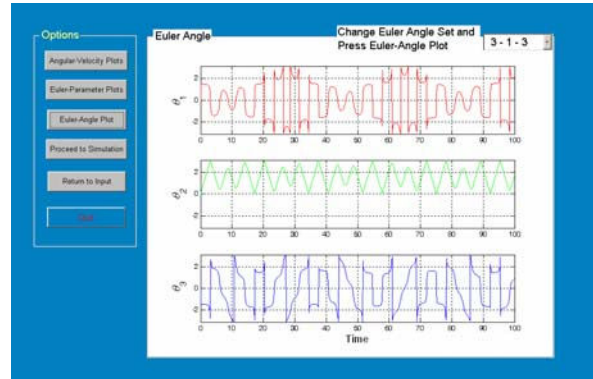
Figure 8. Input screen

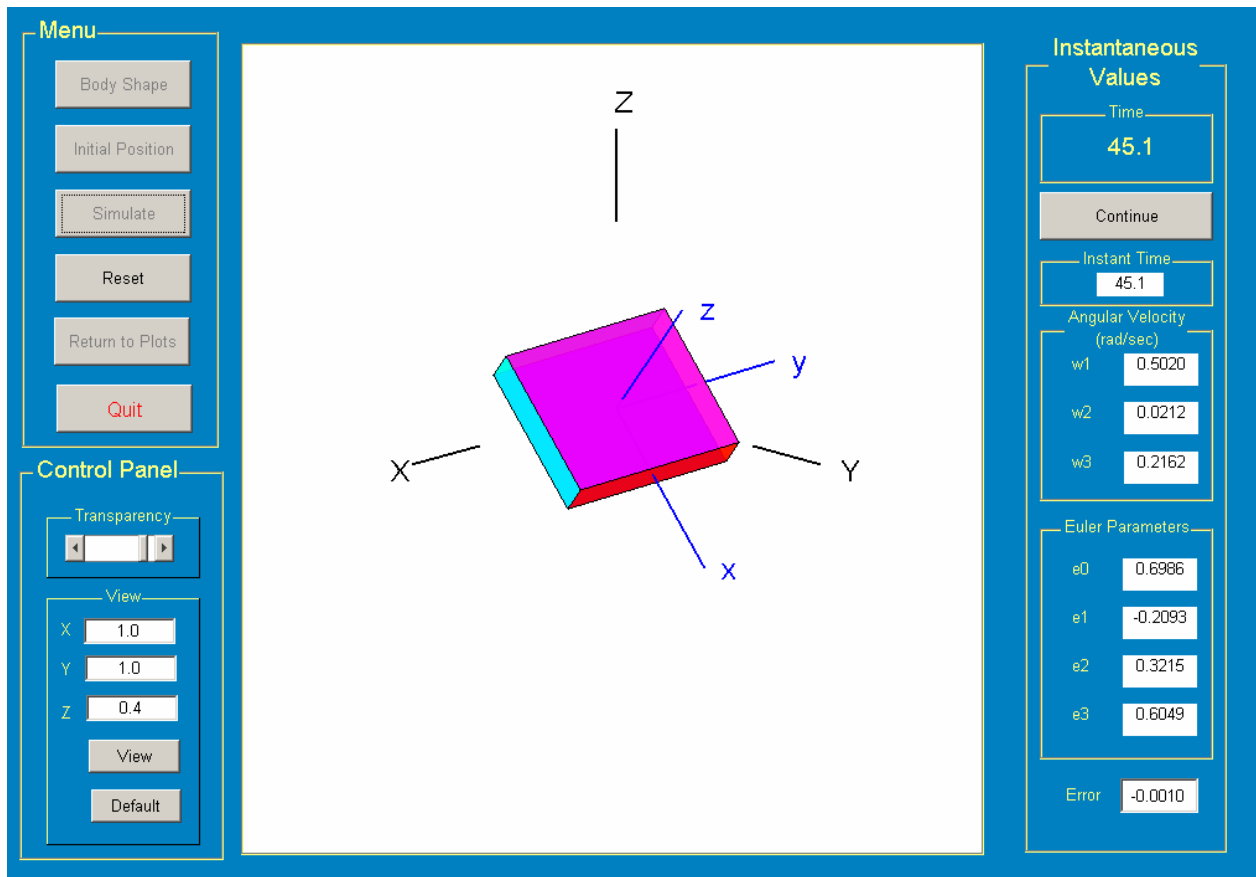Figure 9. Motion parameter plot

Figure 10. A 3-D rigid-body rotational-motion screen (frozen)

Student Response

The vibration software was placed online during the first semester (Fall 2006) of use in the senior–level ESM vibrations class, and it was also occasionally used in class by the instructor as part of the lecture. The students were requested, but not required, to use the software at home in order to enhance their appreciation for changes in the motion conditions. An end-of-semester questionnaire was circulated to approximately 25 students in the class; 13 students responded to questions involving the good and bad aspects of the software and the total number hours that the software was used outside class. Some selected comments, with the total number of hours that the software was used by that student shown in parentheses:

1. "Helps to easily visualize what is happening in vibrations situations. Easy to make changes to those situations." (2 hours)

2. "Gives good visual understanding of what the system is going through. Helped out a lot in the beginning of the semester when I had no idea what was going on and was completely new to the whole subject." (4 hours)

3. "It allows you to better visualize the actual systems." (4 hours)

4. "It was nice to have to verify my own work and/or better elucidate the theory presented in class." (6 hours)

5. "It has a nice user interface and it was not difficult to figure out how to use it." (1 hour)

Following is a comparison of the final grade received in the course along with the average number of hours that the software was used by the students receiving that grade:

A: 3.0 hours   C: 2.25 hours   F: (No responses)

B: 0.7 hours   D: (No responses)

There appears to be little, if any, correlation of the letter grade with the amount of use of the software.

Concluding Remarks

Animation software for critical areas of the standard senior/first-graduate-level vibrations course and the typical upper-level dynamics course has been presented. The student comments on the vibrations software were very positive, but there was no clear relationship between usage and the final course grade.

Acknowledgments

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