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ABSTRACT

A Java Powered Virtual Laboratory (VL) has been developed for conducting nonlinear dynamic analysis of buildings and has been made available on the internet (<http://cee.uiuc.edu/sstl/java/>). This virtual laboratory provides students and practitioners a means to interactively gain fundamental understanding and intuition about earthquake engineering and structural dynamics. By accessing this on line software, remote users are able to analyze buildings with a different number of stories using various structural models and design parameters. Dynamic analysis of the structure can be performed using four historical earthquakes as well as a sinusoidal excitation. Animation of the structural responses is also provided to visualize the dynamic behavior of the building.

BACKGROUND

Educators must always strive to better prepare the next generation of structural engineers who can understand and effectively deal with the design of earthquake resistant structures to reduce the associated human and financial losses. One of the challenges of teaching students about the fundamentals of earthquake engineering is giving them an intuitive understanding of the dynamics of structures. Demonstrating the concepts of dynamics using static chalk boards or books is difficult. The best approach is through hands on laboratories. Unfortunately, few instructors have the necessary facilities readily available to demonstrate structural dynamic concepts.

OBJECTIVES

The objectives of this research are to provide a means for on line interactive experiments, and to increase understanding and provide a conceptual “feel” of dynamic analysis and design.

METHODS

This VL was programmed using the Java. The Java programming language offers significant advantages because of its minimal dependence on the operational platform. Therefore, this VL can be accessed universally over the internet. The Java language also requires a minimum amount of administration maintenance for the VL once it has been developed and published on the internet. If additional updates are required, they can be made locally and put on the internet. When remote users access this software the next time, they will automatically download and run the updated version. In addition, the VL’s interactive interface, optimized with Java programming, significantly increases the efficiency of presenting and, in turn, understanding of a wide range of topics of earthquake engineering.

Four types of models are provided in this VL to describe the dynamic behavior of the structure. These models (illustrated in Figure 1) include: (i) linear stiffness and linear viscous damping; (ii) linear stiffness and nonlinear power law damping; (iii) hysteretic stiffness using the Bouc Wen model and linear viscous damping; and (iv) hysteretic bilinear stiffness and linear viscous damping. By choosing various nonlinearities, users are able to analyze different types of structures using this software.

Computational analysis of the dynamic problems in this virtual simulation utilizes several state of the art numerical algorithms. The general alpha method was employed to solve the hysteretic bilinear stiffness problem and the Runge Kutta method was applied to handle all other linear and nonlinear analysis. These computation algorithms were first verified by programming in Matlab and then translated into Java. It is worth noting that the time step of the numerical algorithms is important to conduct an accurate dynamic analysis. A smaller time step might be needed as the structure gets stiffer. The time step in this VL can be specified and the earthquake data are re sampled when the time step is changed. Accurate results have been obtained by using these numerical methods.

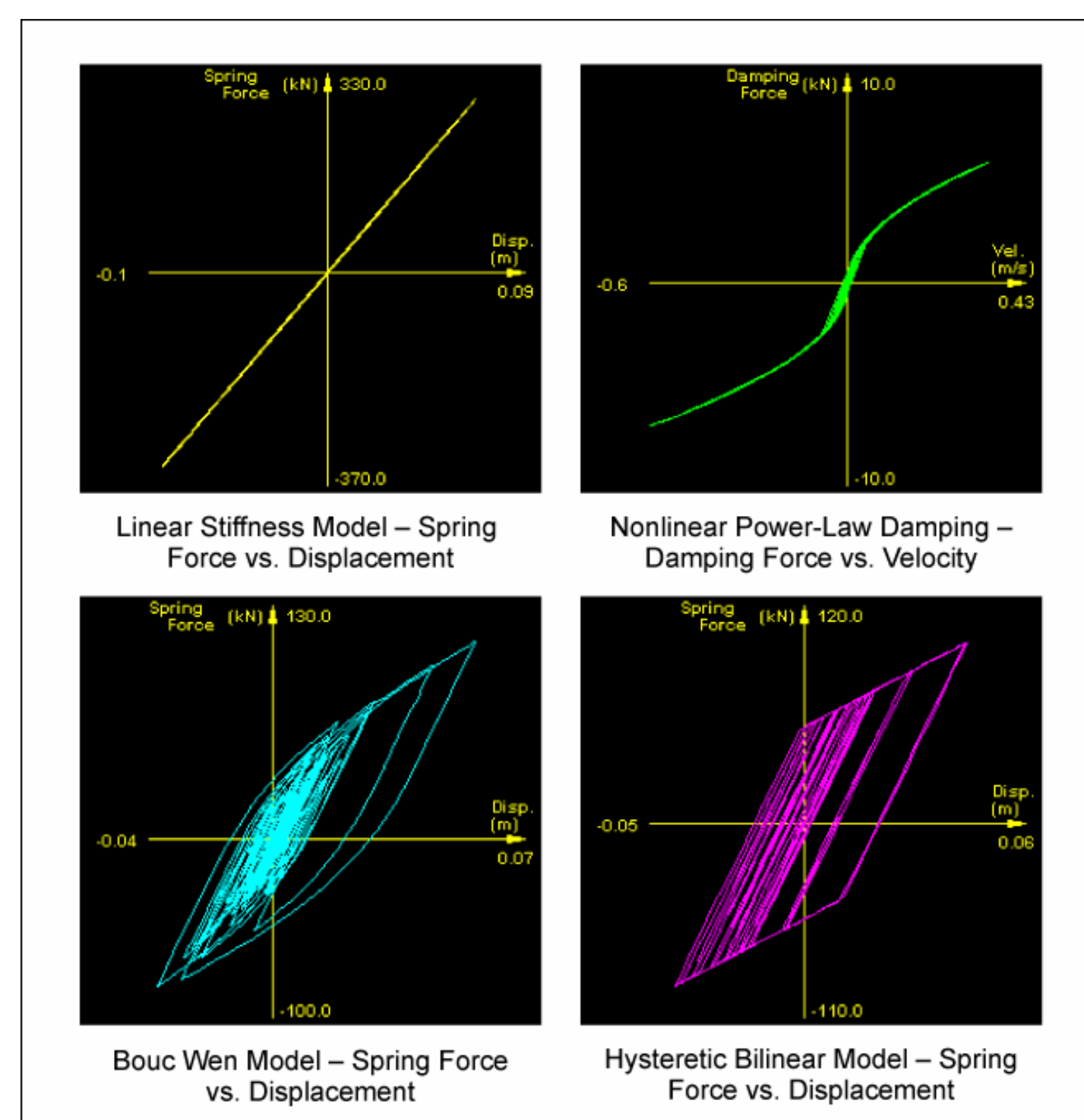


Figure 1. Typical relationship between force and response for different nonlinearities

RESULTS

The interface of the VL is provided in Figure 2. There are four response frames on the left of the user interface. On the right, there is a panel to control the structural analysis and input parameters. There is also an animation panel which provides the animated response. This panel is shown in Figure 3. The control panel and animation panel are interchanged with each other by clicking the “Show Virtual Model” or “Show Control Panel” button.

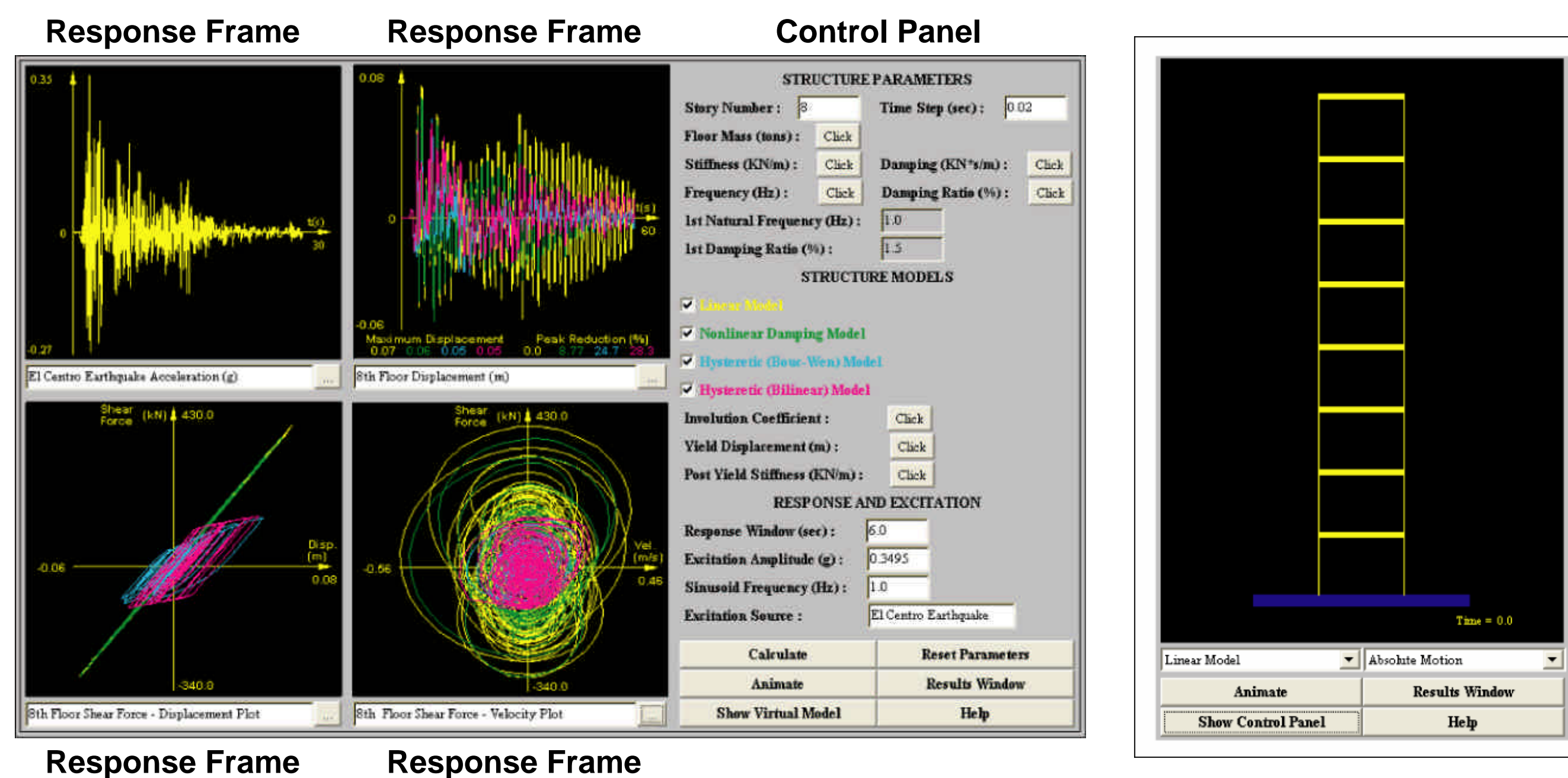


Figure 2. Java-Powered Virtual Laboratory

Figure 3. Animation Panel

The control panel allows users to select the parameters and analyze the structure. The number of stories in the building can be changed, and the time step can be modified as well. Structural parameters, including floor mass, story stiffness and damping coefficients, can be varied by clicking the selection button following the label. Modal properties, including natural frequency and damping ratio, are automatically computed when structural parameters are changed. For convenience, the first natural frequency and the damping ratio are shown in the control panel.

Users can see the response of the structure for each of the four analytical models by clicking the check box under the label “Structural Models”. The associated parameters for these models, including an involution coefficient for nonlinear damping model, yield displacement and post yield stiffness for nonlinear stiffness model, can be changed as well. Users are also able to control the excitations and the manner in which animation is shown by modifying the related parameters in the control panel. By pushing the “Show Virtual Model,” users can toggle between the control panel and the animation panel to help visualize the dynamic response using an animated virtual building.

Various analytical results can be displayed in the response frames. The top right response frame shows an example of the time history response. In this example, the 8th floor inter story drifts for all the selected structural models are displayed simultaneously. It also shows the maximum response values and the corresponding peak reduction factors, which is the reduction relative to the linear elastic case. By viewing the time history and peak reduction factor for different nonlinearities simultaneously, users can easily appreciate the difference between these nonlinearities under the specified excitation. Similar time history plots for relative velocity, absolute acceleration, spring force, damping force, and shear force are also readily displayed by clicking the selection button in each of the four frames. The bottom two response frames demonstrate the relationships between shear force and displacement and between shear force and velocity. Similar plots for spring force and damping force can also be shown by clicking the selection button in any one of these four frames.

CONCLUSIONS

A unique Java Powered Virtual Laboratory has been developed to facilitate the understanding of a wide range of topics of earthquake engineering and dynamic analysis. Participants are expected to gain fundamental understanding of these topics by conducting on line numerical experiments using this interactive software. Other available virtual laboratories, including structural control using tuned mass dampers (TMD) and hybrid mass dampers (HMD), and base isolation using linear and nonlinear devices, can be found at <http://cee.uiuc.edu/sstl/java/>.

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