

## ABSTRACT

The Virtual Laboratory (VL) for Experimental Structural Dynamics is educational software which simulates the laboratory environment. This VL provides various features of the dynamic experiment such as sensors, anti-aliasing filter, data processing, etc. A multi-story shear building is employed as the test bed and the responses of the structure are obtained through the linear/nonlinear dynamic analysis. The VL is available on-line at <http://sstl.cee.uiuc.edu/java/esd/VirtualLab.html>.

## BACKGROUND

Hands-on experiment is one of the best ways to learn about the complex dynamic behavior of structures. However, the necessary experimental setup is in most cases not available to use due to, for example, high cost. Especially, since it is not possible to damage the test structure at all times, nonlinear dynamic behavior is quite difficult to observe. To overcome these difficulties, a series of VLs is developed which are Control VL, Base Isolation VL, Nonlinear Dynamics VL, and Experimental Structural Dynamics VL. The VLs are expected to replace such expensive experimental instruments particularly in the educational field. This poster is mainly focused on the recently developed Experimental Structural Dynamics VL.

## OBJECTIVES

The objectives of this research are to provide a means simulating the laboratory environment and to give users an insight into the dynamic experiment.

## METHODS

Since the VL is designed to simulate the laboratory environment, the essential parts of the experiment such as structural parameters, data measurement and processing are provided. With the user-defined parameters for the virtual experiment, the VL calculates the structures responses through the linear/nonlinear dynamics analysis and displays the results.

### Data measurement

One primary part of the experiment is data acquisition in which responses of the structure such as displacement, acceleration, etc. are measured and discretized before data processing. The VL provides unique features of experiments regarding data measurement. Users are allowed to put sensors on specific floors which they want, and only measured responses are processed after the numerical integration. A total 6 kinds of sensors are available: displacement, velocity, acceleration, spring force, damping force, and shear force. To prevent memory problems, the maximum number of sensors is limited to 8, and it is also limited in the real world. Since the noise is inevitable in measuring data, it is important to consider the level of the ground excitation and measured responses from 0% to 5%. The measured (calculated) response of the structure is divided into smaller data segments with the length of the number of fast Fourier transform (FFT). The number of averages and FFT, the sampling time, and overlap between windows determine the length of measuring time. Anti-aliasing filters are simulated in the VL. Aliasing is associated with the sampled data and occurs whenever the data contains frequency components larger than the Nyquist frequency. The 8 pole elliptic filter is implemented in the VL to simulate the anti-aliasing filter.

### Data processing

The measured data is then processed to extract the dynamic characteristics of the test structure from FFT calculation. Since the finite length of data always results in the spectral leakage problem, the windowing technique is usually employed to minimize the leakage in data processing. The VL supports 3 kinds of windows, which are Boxcar, Hanning, and Hamming windows. Using the FFT of the data the VL computes power and cross spectral density, transfer function, auto and cross Correlation, coherence, and impulse response.

### Structural model and computational method

To portray the structure, four models are used, which include linear stiffness and linear viscous damping; linear stiffness and nonlinear power-law damping; hysteretic stiffness using the Bouc-Wen model and linear viscous damping; and hysteretic bilinear stiffness and linear viscous damping. Use of nonlinear models shows the users how the nonlinearity of the structure affects dynamic characteristics. Runge-Kutta and Generalized Alpha methods are used in numerical integration for the AA filter and structure.

## RESULTS

The user interface of the VL is shown in Figure 1. There is two response plot panels on the left of the user interface. An animation panel on the center shows the animated building. There is a control panel on the right, on which parameters for the virtual experiment are provided. Note that users can toggle between the animation panel and two response plot panels by clicking 'Show Virtual Building' or 'Hide Virtual Building' buttons on the control panel.

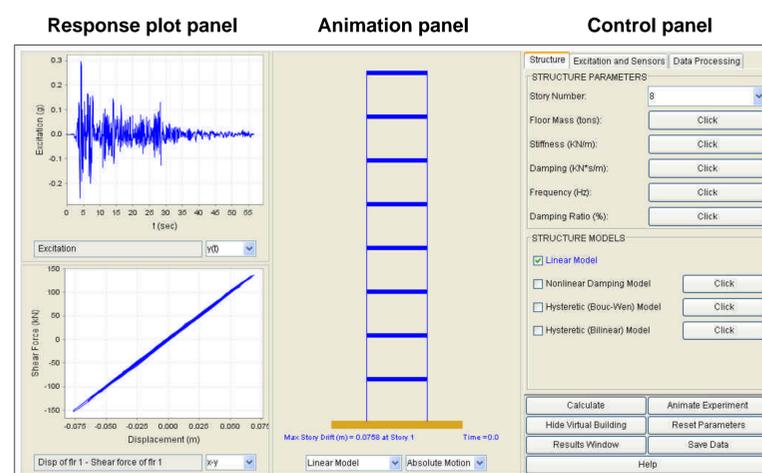


Figure 1. User interface of Virtual Laboratory

Measured responses and various functions related to spectral analysis can be displayed on the response plot panels, two of which are located on the right of the simulator and the other two are hidden under the animation panel. Users can choose what they want to see by using the drop-down menu under each response plot panel, which will open "response selection window". Functions which users can choose on the drop-down menu are time history of the excitation or responses, response vs. response plot, FFT, power and cross Spectral Density, transfer function, auto and cross correlation, coherence, and impulse response.

## CURRENT ACTIVITIES

Currently, a new Java-powered Virtual Laboratory is being developed to increase student understanding earthquake engineering design. Shown in Figure 2, this new VL illustrates important concepts such as response spectrum analysis, force reduction factor and design spectrum.

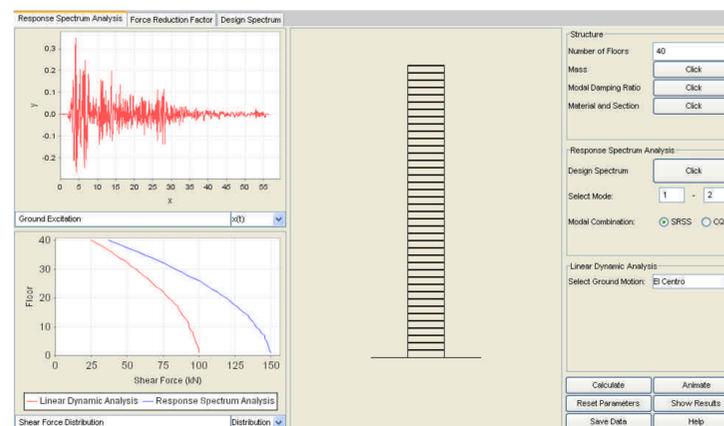


Figure 2. Virtual Laboratory for Earthquake Engineering

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