

Structural Dynamics Virtual Laboratory: A Learning Tool Kit for Young Engineers and Practicing Professionals

by

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Structural Dynamics Virtual Laboratory: A Learning Toolkit for Young Engineers And Practicing Professionals



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ABSTRACT:

India has been facing earthquake problems from many centuries which need no introduction. From recent earthquakes, it is very well understood that lack of awareness is one of the major factor for huge casualty losses. While still having the probability of occurrences of earthquakes in India, it becomes very important and need to increase the awareness about the effects of earthquakes among growing professionals involved in construction by making them understanding the concepts of Structural Dynamics and Earthquake Engineering.

This paper will detail the use of virtual laboratory in real time environment of structural dynamics. Virtual Laboratory provides a new methodology to convey and learn concepts using the power of visualization of ideas and computations. Virtual labs rely on an active engagement of the learner in the knowledge acquisition process. This paper is aimed at promoting the new methodology and providing a glimpse into the exciting world of interactive and experimentation of structural dynamic concepts with no limitation of conductance. Using this tool, a person with little knowledge of structural engineering can enhance his fundamentals of structural dynamics. For better understanding experiments are explained with graphical diagrams seen in GUI with the support of JAVA 3D. Apart from basic understanding of dynamic behavior of structure, this tool kit also helps architects and young civil engineers in understanding the principles of structural dynamics.

Keywords: Structural Dynamics, Virtual Laboratory, Interactive

1. INTRODUCTION

More than 60 % of India's area is prone to earthquakes and the land which was considered to be stable continental region has also seen major earthquakes in past twenty years. The losses were huge in both human and property (Murthy CVR). Proper awareness of earthquakes and its effects on building behaviour would decrease the losses. As Indian country is said to be a developing nation a large transformation is taking place in building the Infrastructure in two dimensions one being public and other personal in large scale. So there is an urgent need to send the youngsters with proper awareness and understanding of earthquakes, its effects on structures to construction industry. At the same time it will be more advantages if the current practising engineers also get a chance of knowing the effects of earthquakes on structures.

One of the major drawbacks is that the average civil engineer in the country is not getting enough formal training in the concepts of structural dynamics and earthquake engineering during his/her education. There are many reasons for that one being more number of engineering colleges with improper availability of labs to students and other being huge expenditure for conducting real-time experiments, at the same time it is very difficult to repeat the same experiment many times for proper understanding.

In this scenario, with the help of latest technologies a new way of conducting the experiments have emerged in to the present education through virtually. The virtual laboratory can be defined as laboratory experiment without real laboratory with its walls and doors. It enables the learner to link between the theoretical aspect and the practical one, without papers and pens. It provides the students with tools, materials and lab sets on computer in order to perform experiments subjectively or within a group at anywhere and anytime. It is a unique opportunity to boost the quality of engineering education, deepen understanding, and provide the necessary practical skills to young minds through cost effective outreach and distance learning activities.

Simulations in virtual labs are developed based on two different types of data generation one being formula based and other lab experiment data recorded. For simulation where formulas can be used their data's are obtained from text book formulation and 3D simulations are shown. But in some cases where failure of material takes place which cannot be derived from a formula, in those cases real data from lab manuals where the experiments are already conducted that data has been recorded will be used for generating simulations.

1.1 Literature Review

Virtual labs are intended to address the need for access to good lab facilities. Virtual Labs also provide remote-access to Labs in various disciplines of Science and Engineering. These Virtual Labs would cater to students at the undergraduate level, post graduate level as well as to research scholars. Virtual laboratories are defined here as one genre of interactive multimedia objects. Interactive multimedia objects are composed of heterogeneous formats that include text, hypertext, sound, images, animations, video, and graphics (Buddu M, 2002).

Felder, R.M 1988 has observed that the large percentage of engineering students have shown predominant inclination towards virtual laboratory to conduct virtual experiments. Didier et al, 1995 have first time floated a practical course using virtual lab in electrical engineering department where student feedback is analyzed and the evaluation result is found to be very positive and encouraging. Elizabeth et al, 2002 have used virtual laboratory for experiencing with a smart bridge test and found that it is very much cost effective, convenient, lesser time-consuming and importantly repeating the experiment was easier. James et al, 2008 used virtual labs for teaching operating system concepts and found a very good response from students understanding. Similar to James et al, 2008, Hein-Dietrich et al, 2005 have used virtual labs for teaching digital system design and compared with remote labs.

In the engineering field virtual labs have become common usage, a number of investigators have developed interactive laboratories for different engineering disciplines. For example a special IEEE journal issue is dedicated entirely to virtual laboratories in the areas of mechanical, electrical and biomedical engineering (Sushil K et al, 2011). Bhargava et al, 2006 have developed a virtual torsion laboratory for teaching concepts related to torsion in different materials. Hashemi et al, have developed for solid mechanics, Jia, R et al, 2006 have developed for fluid mechanics, Buddu M, 2002 have developed virtual laboratories for civil engineering.

1.2 Objective of VSDL

To address the above mentioned issue, we developed Virtual Structural Dynamics Laboratory (VSDL), where a faculty/student with some knowledge on structural engineering can be able to learn by him/her the fundamentals of structural dynamics. This virtual laboratory developed allows the control of all experiments for introductory courses in structural dynamics, with a satisfactory level of interactivity; such a laboratory can be used for illustrating experiments. This is a web-based innovative tool aimed towards a better understanding of experimental methods. These virtual labs are compatible with all web browsers, as well as with different operating systems.

To provide a complete Learning Management System around the Virtual Labs where the students can avail various tools for learning, including additional web-resources, video-lectures, animated

demonstrations and self evaluation.

2. STRUCTURAL DYNAMICS VIRTUAL LABS

Structural dynamics is a concept of structural engineering which deals with the behavior of structures subjected to dynamic loadings like wind, earthquake and blasting. Any structure can be subjected to dynamic loading. Dynamic analysis can be used to find dynamic displacements, time history and for modal analysis. In this virtual structural dynamics laboratory, the student can perform tests on different types of structures for different ground motions (earthquake data). These conditions and/or constraints are designed to reinforce classroom theory, by performing required tests in this virtual lab, analyze subsequent data, and compare the results with theory. For results, graphs and tables are generated after completion of computing experiment.

This lab covers all the procedure steps and required technologies to perform an end-to-end design assessment in each module. While designing the multi-storey structures, this lab is helpful to the engineers to get an idea about vibration/response of structures under dynamic excitations. It is very much useful for students to understand the concepts of Structural dynamics.

2.1 List of experiments

The Fig. 1 shows the main page of structural dynamics virtual lab. This lab consists of ten virtual experiments which are shown by their equivalence images with the thumbnail button options. The selection of button redirects you to its corresponding experiment. For instance, the clear description of Forced Vibration of Single Degree of Freedom experiment is explained in Fig. 2.

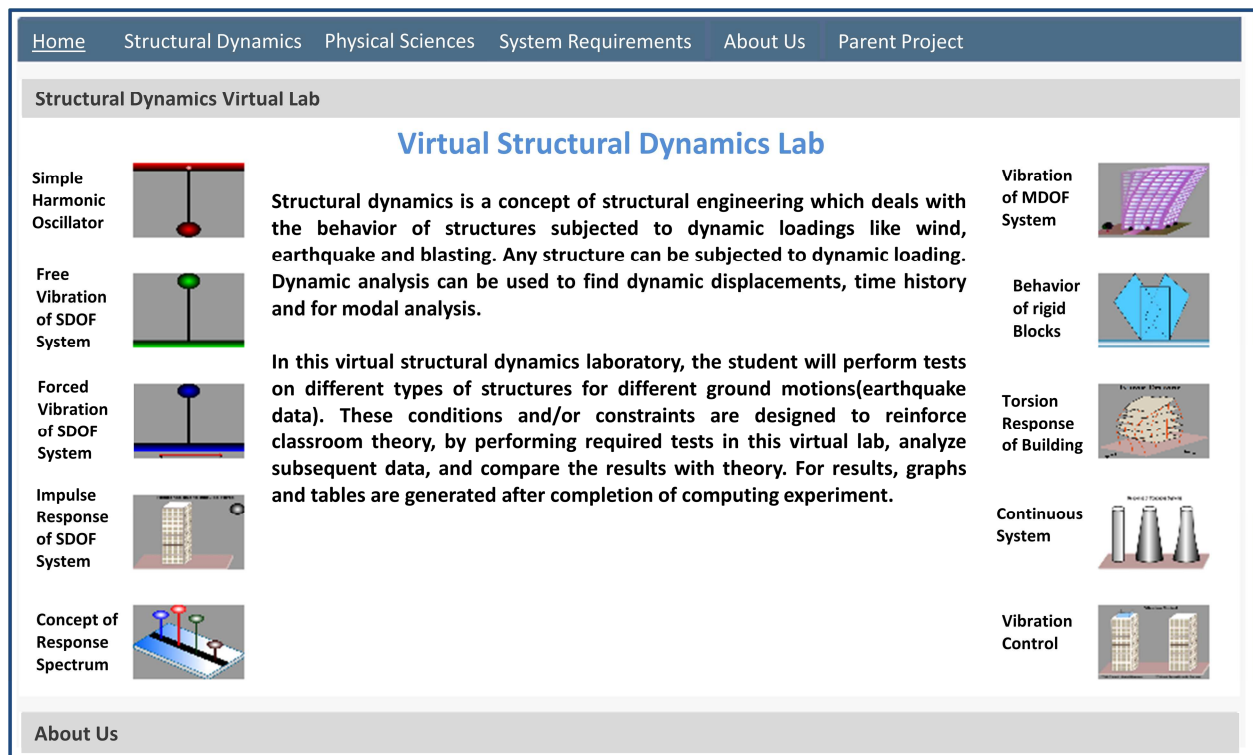


Figure 1. Snapshot of homepage of Structural Dynamics Virtual Lab

2.2. Forced Vibration of Single degree of freedom – A case study

The Fig. 2 shows forced vibration of single degree of freedom page in virtual lab. For the clear representation of experiment the figure is labeled with alphabets. The whole page is segmented into

different perception areas. Every button is linked up with its corresponding page, so by clicking the button user can redirect into new page.

In the figure, label (a) covers the introduction part of the experiment. Introduction is a beginning section which states the purpose and goals of the experiment. It is the first phase where the people see, hear, or experience about experiment so the reader can follow experiment in clear perception.

Label (b) covers the objective of experiment. In general, an objective is broader in scope than a goal, and may consist of several individual goals. Objectives are a basic tools that underlying all planning and strategic activities.

Label (c) covers the theory of experiment. Theory presents the concept of experiment that is testable. It is used to provide a model for understanding the concept.

Label (d) covers the manual part of experiment. The manual part describes the procedure for experiment. The user can perform operation on experiment with the support of manual theory; it provides step wise process and observations.

Label (e) shows the link button. In the introduction area after completion of introduction part, the button is included which takes you to the explaining the complete experiment using flash animation through stepwise procedure.

Label (f) takes you to the virtual lab experiment. Here the user can perform experiment with appropriate input parameters which is shown in Figure 4 and detailed explanation is given in section 3.

Label (g) covers the quiz of experiment. A quiz is a test of knowledge obtained after conducting experiment virtually. It is the self assessment used to measure the knowledge of users. This will improve ability and knowledge in the subjects. Quiz can be written any number times.

Label (h) gives the references which have been used for making this experiment. Extra references are added for additional information regarding the same experiments in little more detail.

Label (i) will take you to the home page which is shown in Fig. 1.

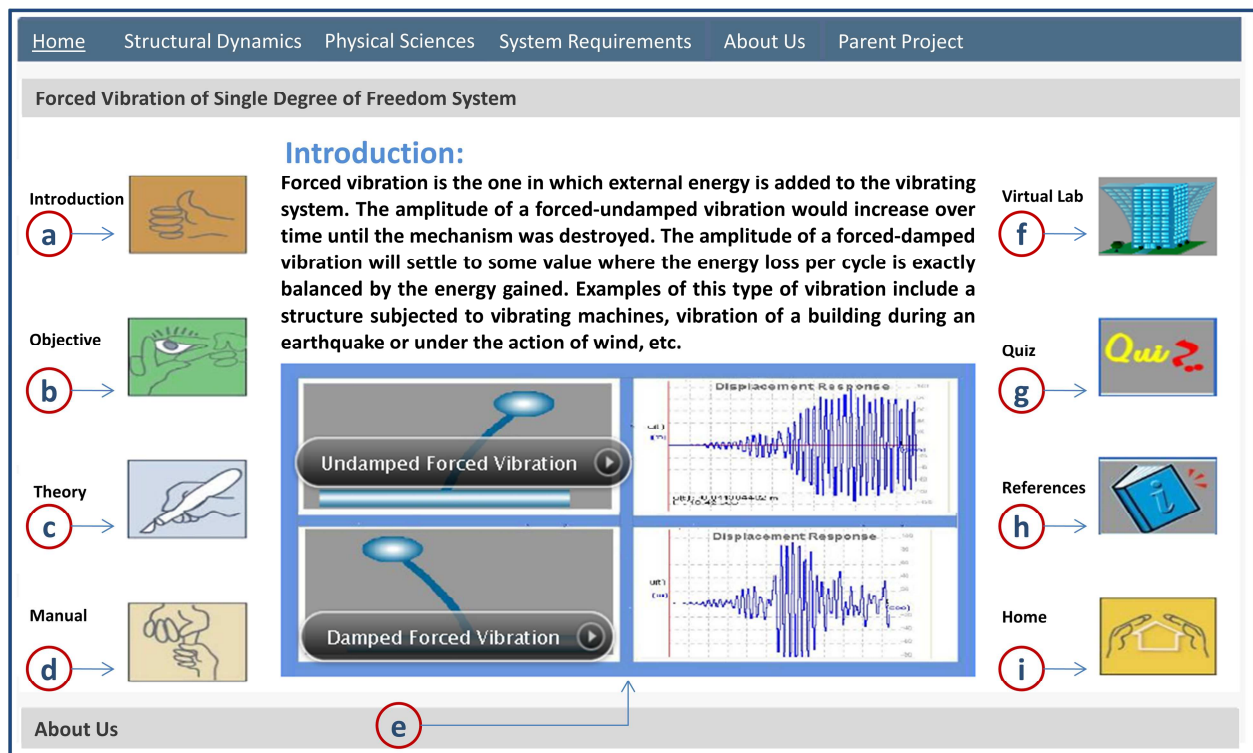


Figure 2. Snapshot of the Forced Vibration of Single Degree of Freedom System showing different links.

All the labels in the Fig. 2 are user friendly; user can move from any label to label and not necessarily to be in sequence. Sequence flow will only give information regarding experiment in an organized way.

3. VIRTUAL LAB

3.1 Design flow of conducting Virtual lab experiment

All the virtual labs developed will follow the flow chart as shown in the Fig. 3. When a user starts the virtual lab for the first time, all the parameters are set with default values so the user without any confusion can run the virtual experiment. During the simulation user has a choice to view the lab in two views, horizontal view and vertical view. User can click on any of the button to feel like going around the lab setup virtually if in any case user is not interested in views a default view will be seen through out the experiment. During this entire time user always have a choice of going to main page and change the parameters for restarting the experiment.

Once the entire simulation runs then the user can see the results obtained for given input parameters or default parameters. Show results check box will show the graphs obtained, now the user can interpret the results and compare them to the read manual. At this stage the user can go to another lab or restart the whole experiment once again to perform the experiment.

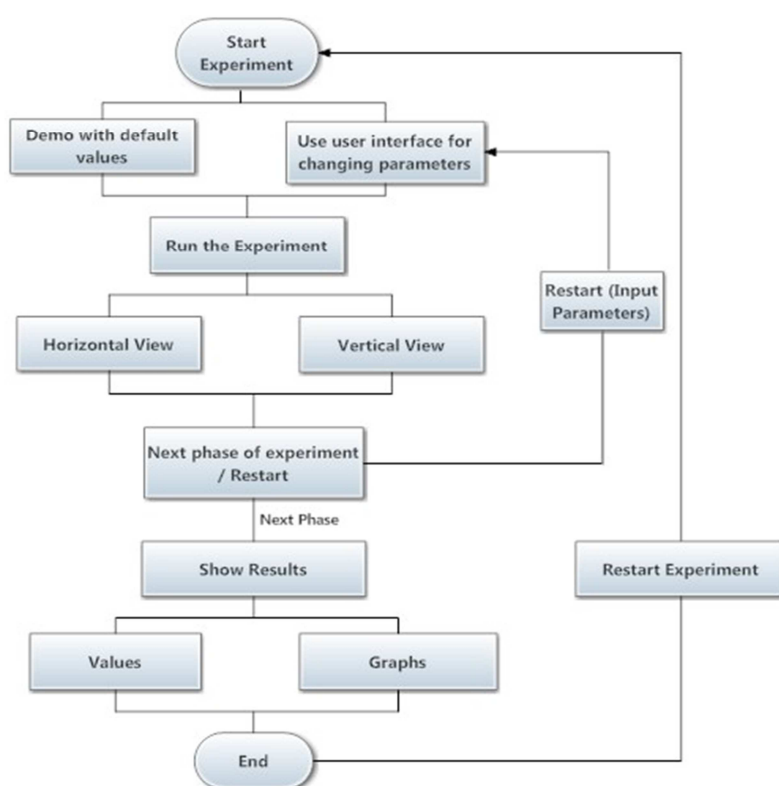


Figure 3. Design flow of Virtual lab experiments.

The Fig. 4 shows the virtual lab experiment. The figure is labeled with alphabets for clear explanation. The whole experiment is developed by creating panels, i.e. bottom panel, simulation panel, top panel, right panel and these panels are aligned respectably to south, center, north and east. The label (a) is a user interface panel (bottom panel) which is used to change input parameters of the experiment. The user interface (UI) is everything designed into an information device with which a human being may interact -- how an application program or a Web site invites interaction and responds to it. The user can vary or change the parameters according to theory part for the appropriate results. The interface is actually made up of several independent windows. The sizes and arrangements of these windows are flexible to allow for the varying needs of different experiments. So there is one canvas user friendly pane is designed to make the changes in experiment. It is the main work area of the interface, where you can view and manipulate elements of your experiment. This pane can be hidden to maximize the

view of actual experiment, by clicking the change parameters checkbox it will be pop-up for the viewers. The above sample user interface pane is designed for one experiment, which controls to create and edit elements in your experiment, such as text, values, shapes etc. This pane contains combination of slider controls, activation checkboxes with the representation of icons and different kind of menus where the user can manipulate data. The clear description of every element in the pane is described as follows,

The label (b) is a slider control, it defines where you can drag the scale slider, drag left to decrease the value of corresponding option and drag right to increase their value. Sliders are used for settings where the value of the parameter is a number chosen from a range of numbers. They are by far the most common control type in Motion, mainly because of their versatility. The label (c) is an activation checkbox, which define any parameter that must either be on or off uses a checkbox control. By clicking these checkboxes, it will redirect to another window. Label (d) is a parameter selection menu. It is a special type of pop-up menu, specifically for Parameter behaviors. When a Parameter behavior is applied to an object, you need to identify which parameter the behavior should affect. You can choose from the pop-up menu, which lists all current parameters. . And the center panel is a simulation panel where the 3D rendering can be done.



Figure 4. Snapshot of the virtual lab showing different parameters.

The label (e) is a top panel which shows the experiment process. Every experiment is designed in some phases. This navigation pane appears at the top of the experiment. This pane contains three buttons that allow you to see and manipulate different aspects of the current experiment and navigates to the next phase. These buttons perform some functions in the experiment. You can manipulate experiment like stop, restart and move to the next phase. This isolation buttons takes you to previous and next views of experiment. The label (f) is a pane used for representation of calculated results. The user can change input parameters before the experiment starts. After completion of experiment the corresponding output parameters which are calculated during the operation will appear on this pane.

The label (g) is designed to view the experiment. The traditional camera-based view model, places a virtual camera inside a geometrically specified world. The camera "captures" the view from its current location, orientation, and perspective. The visualization system then draws that view on the user's display device. The application controls the view by moving the virtual camera to a new location, by changing its orientation, by changing its field of view, or by controlling some other camera parameter. Camera-based view models emulate a camera in the virtual world, not a human in a virtual world. The Java 3D view model incorporates head tracking directly, if present, with no additional effort from the developer, thus providing end users with the illusion that they actually exist inside a virtual world. The Isolate button appears in experiments that contain a camera. Once a camera is added to the experiment, all groups are converted to 3D. If you choose Keep as 2D in the New Camera dialog, the camera is added to the experiment, but the groups remain 2D groups. Once a camera is added to the experiment, the Isolate button appears for any selected group, layer, or camera. The button has an active and inactive state. Clicking the Isolate button for a layer or group sets that object to its original face-forward orientation. Clicking the button again returns to the previous view. Clicking the Isolate button for a camera takes you to that camera's view. In virtual lab we are presenting the experiments in horizontal and vertical camera views. In the camera view model, for both horizontal and vertical views timer for camera simulation is created.

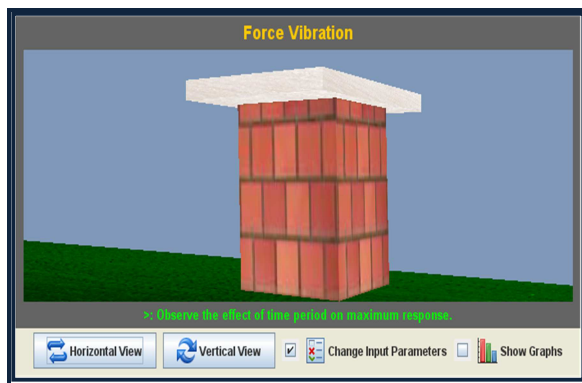


Figure 5.1. Horizontal view of Experiment

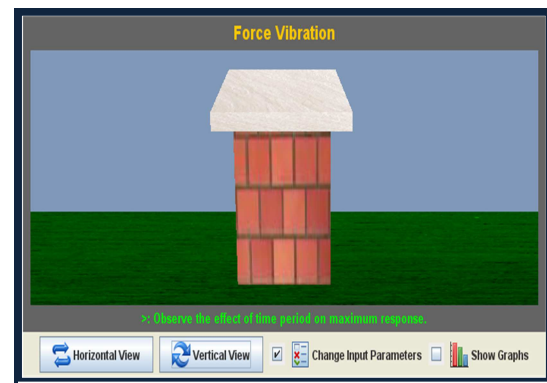


Figure 5.2. Vertical View of Experiment

The various parameters that users control in a camera-based view model specify the shape of a viewing volume (known as a frustum because of its truncated pyramidal shape) and locate that frustum within the virtual environment. The rendering pipeline uses the frustum to decide which objects to draw on the display screen. The rendering pipeline does not draw objects outside the view frustum, and it clips (partially draws) objects that intersect the frustum's boundaries.

Though a view frustum's specification may have many items in common with those of a physical camera, such as placement, orientation, and lens settings, some frustum parameters have no physical analog. Most noticeably, a frustum has two parameters not found on a physical camera: the near and far clipping planes.

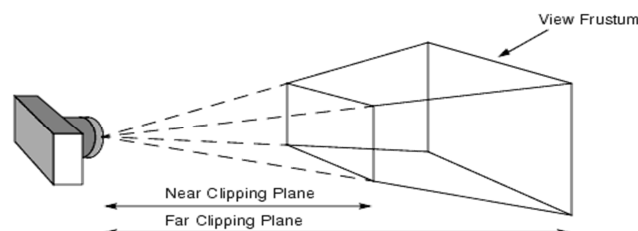


Figure 6. View Frustum (Ref: Java 3D API – View Model)

The location of the near and far clipping planes allows the application programmer to specify which objects Java 3D should not draw. Objects too far away from the current eye point usually do not result

in interesting images. Those too close to the eye point might obscure the interesting objects. By carefully specifying near and far clipping planes, an application programmer can control which objects the renderer will not be drawing. From the perspective of the display device, the virtual camera's image plane corresponds to the display screen. The camera's placement, orientation, and field of view determine the shape of the view frustum. The label (h) is a right panel which shows the graph and input and output parameters. A graph is a diagram which shows the relation between two variable quantities. By the generated results of experiment the graph is designed for better graphical representation of data and relationship.

All these virtual lab methods include: gaining attention, informing students of the objective, stimulating recall of prior knowledge, presenting the stimulus, providing learning guidance, eliciting performance, providing feedback, assessing performance, enhancing retention and transfer of learning. In virtual labs, the user cannot break any equipment, he/she does not require space and can he/she can conduct a variety of tests that is beyond the scope of physical lab.

3.2 Results from virtual lab

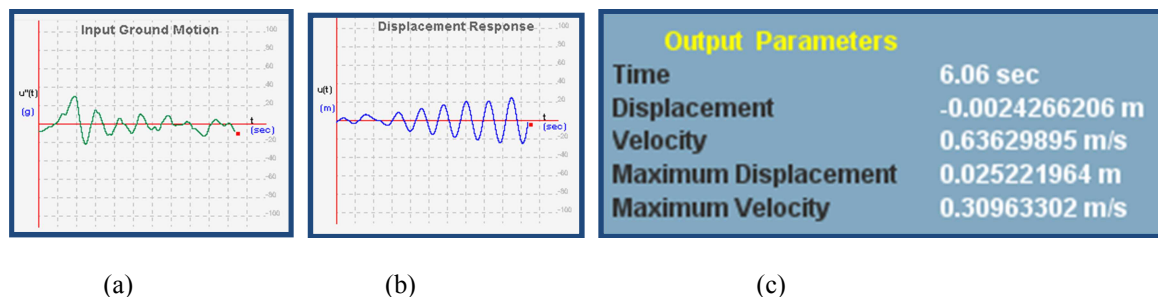


Figure 7. Understanding the results. (a) Input of ground motion (b) Response of the SDOF (c) Output parameters for given ground motion

When the test is completed the user must now interpret the results. Virtual Labs will provide to the students the result of an experiment by one of the following methods (or possibly a combination). Modeling the physical phenomenon by a set of equations and carrying out simulations to yield the result of the particular experiment. This can at the best provide an approximate version of the real-world experiment. Providing measured data for virtual lab experiments corresponding to the data previously obtained by measurements on an actual system.

3.3 Maintenance of virtual lab

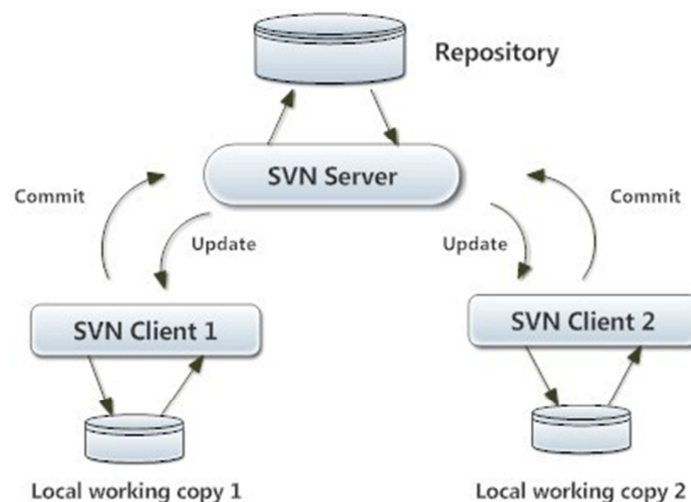


Figure 8. SVN server client structure

The virtual lab project is maintained with the help of SVN server. The whole project files are stored in a repository which is connected to the server. SVN server is a software versioning and revision control system distributed under an open source license. Developers use Subversion to maintain current and historical versions of files such as source code, web pages, and documentation. If you are running a project, there is no doubt that today or tomorrow you shall need a version control system. A version control system keeps track of the different versions of a project. Initially create a repository for the project. Now you can connect your repository to the SVN server. Each revision in a Subversion file system has its own root, which is used to access contents at that revision. Files are stored as links to the most recent change; thus a Subversion repository is quite compact. The system consumes storage space proportional to the number of changes made, not to the number of revisions. The Subversion file system uses transactions to keep changes atomic. A transaction operates on a specified revision of the file system, not necessarily the latest. The transaction has its own root, on which changes are made. It is then committed and becomes the latest revision. The figure 8 shows clear imagination. The SVN client who performs commit on the server which is called as revision of that project and it will be updated to the SVN client.

4. CHALLENGES IN VIRTUAL LAB

- Scaling the objects to give the appearance of reality.
- Making experiments to run faster on web.
- Giving the user a three dimensional experience.
- To implement/reach for every educational institution.
- To enhance student learning and making laboratory experience engaging and productive.
- Virtual laboratories are still far from becoming part of many engineering programs.
Incorporation of virtual labs in engineering curricula faces barriers that must be overcome.

5. CONCLUSION

In order to increase the awareness about the effects of earthquakes among professionals involved in construction, it is necessary to make them understand the concepts of structural dynamics and earthquake engineering. To address this issue, we have developed a software tool named Virtual Structural Dynamics Laboratory. This is an easy tool for users to understand structural dynamics. The experiments are used to explain the fundamentals of structural dynamics. In this paper, we described the design and implementation of a virtual, web-accessible interface to a real-world structure. We also described the utilization of our laboratory in an engineering curriculum to enhance the comprehension of physical principles. Virtual labs offer some advantages in engineering education and can supplement physical labs. The user interface in virtual labs must be easy so that the user can spend time learning the discipline concepts rather than the navigation. With the increasing popularity of virtual educational technology, globally and locally, the development of virtual learning environment became an important field of science which has its own basics and principles.

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