NEES CYBERINFRASTRUCTURE:
A FOUNDATION FOR INNOVATIVE RESEARCH AND EDUCATION

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ABSTRACT

This paper provides an overview of the vision and ongoing developments of the cyberinfrastructure component of NEES, the George E. Brown, Jr. Network for Earthquake Engineering Simulation. A core task of this cyberinfrastructure is to archive research data resulting from experiments at a range of NEES equipment sites located across the United States. A new phase of NEES has begun in October 2009, building the cyberinfrastructure on the HUB platform that has proven successful in the area of nanotechnology. A key feature of the new *NEEShub* being created is that it not only provides convenient access to the NEES data repository, referred to as the Project Warehouse, but also hosts a range of tools for data visualization, analysis, and computational simulation that can be invoked directly at the nees.org web site, without the need for software download and installation. This environment provides advanced capabilities for research use as well as for educational purposes.

Introduction

The NEES collaboration today consists of 14 equipment sites for experimental work dedicated to the reduction of earthquake risk. The current experimental reach of the NEES equipment includes tsunami, geotechnical, and structural facilities that can address almost any technical question that may arise on issues related to the response of the built-environment during earthquakes. Development of this massive array of experimental capabilities demanded an intense and sustained effort. As of October 2009, NEES has entered into a new phase, with headquarters at Purdue University. A significant activity of the new NEES leadership team is focused on the development of cyberinfrastructure, which builds on the successes of the previous phase of NEES and, at the same time, pursues new innovation. This paper describes the vision and ongoing cyberinfrastructure developments of NEES.

Cyberinfrastructure Goals

The NEES cyberinfrastructure serves as an integration framework for the 14 NEES equipment sites, the research community, software tools developed at the involved organizations, and NEES education, outreach and training activities. While the NEES sites have already achieved successes in all these aspects as individual organizations, the NEES cyberinfrastructure development aims at creating and increasing synergy among them, producing a network that is more powerful than the sum of its parts.

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The foremost concern for the cyberinfrastructure is the management of the research data resulting from NEES experiments. This paper briefly describes the important issues of data gathering, structuring, viewing and archiving. We have chosen an underlying HUB platform that has proven successful in the science domain of nanotechnology, creating the *NEEShub* that will bring advanced functionality to the NEES web portal at nees.org.

Data…Data…Data

The management of research data is emerging as a central issue in an ever-growing number of science and engineering domains. Because of continuously improving sensor equipment, today one is able to instrument almost any imaginable object, collecting vast amounts of information that can be preserved for future study and historical record. For example, in an earthquake engineering experiment, a specimen may be equipped with hundreds of strain gauges and tens of cameras to observe the effects of an earthquake simulated by a shake table. The data thus collected is used by the researcher to evaluate the behavior of the materials and structural elements, aiming at recommendations for improved designs of buildings and infrastructure.

In addition to the immediate use of the collected data by researchers, the information is of value to those who do not have direct access to the expensive earthquake engineering equipment. By analyzing data that had been collected in experiments conducted by others, scientists can come to new insights, thus increasing the value of the NEES investment. Of key importance for such future research efforts is the accurate description of the scientific details of the conducted experiments and obtained data. Capturing such precise semantics of the experiments requires the creation of underlying *data models*. They describe the experimental setups as well as the meaning of the gathered data and serve as an archiving framework in the *NEES Project Warehouse.*

Figure 1: Envisioned Project Display of a research project in the NEES Project Warehouse

NEESWood Benchmark

PI(s): Dr. J.W. van de Lindt, Dr. R.A. Davidson, Dr. A. Filiatrault, Dr. D.V. Rosowky, and Dr. M. Symans

Date: June 5, 2006 to November 15, 2006

Testing Site: SEESL - University at Buffalo

Project Description

This project seeks to take on the challenge of developing a seismic design philosophy that will provide the necessary mechanisms to safely increase the height of woodframe structures in active seismic zones of the U.S. as well as mitigating damage to low-rise woodframe structures. This will be accomplished through the development of a new seismic design philosophy that will make midrise woodframe construction a reality in regions of moderate to high seismicity. Such a design philosophy falls under the umbrella of the performance-based design paradigm.

NEESWood Benchmark Test Structure

Sponsor: National Science Foundation Grant: CMMI-0529903 and Grant: CMMI-0402490

Keywords: Seismic Design, Woodframe Construction, Performance-based Design

Equipment

Main Equipment	Description
Shake Table	Shake Table Facility

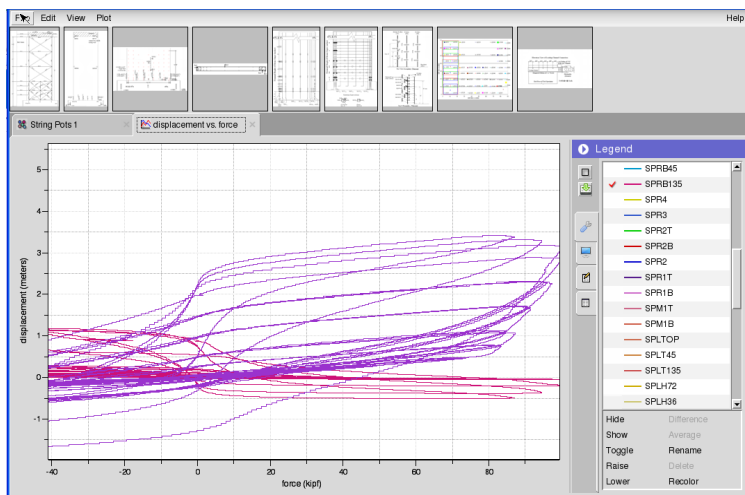**Detailed Equipment List** (view)

Tools for viewing archived research projects and visualizing the captured data are most important for the end user. Our ongoing software developments aim to provide a more convenient user interface than is currently available in the NEES Central data repository. Figure 1 shows a vision of a Project Display under development. This Project Display summarizes the key aspects of an experiment such that an end user can decide whether the experiment is of value to them. A key capability within this new

environment is the visualization and inspection of data directly in the NEES Project Warehouse without the need to download large data amounts to a local computer. Figure 2 shows a prototype data visualization tool that executes directly on a web browser, interfaces with the data repository, and provides visualization of the data from a NEES project.

Among the data management challenges are the creation of data capturing, curation, archiving, and long-term preservation capabilities that support the research community in the best possible way. We will continue to support the present data acquisition methods and tools that are in use, including existing telepresence tools (such as DataTurbine, FlexTPS, RDV) that allow researchers to view an experiment in progress from a remote location. Archived data is not meaningful if there is insufficient information about the experiment in which the data was captured. Metadata describes such information. We are moving away from a process in which a Data Curator adds metadata in the archive *after* the researchers have uploaded their results. Our new method of *curation at the source* will provide tools through which

Figure 2: A data visualization tool executing directly on the NEEShub

researchers fully describe the meaning of their experiment and captured data upfront. The key improvement is that the tool derives the necessary metadata, which becomes part of the archived information. Long-term preservation needs of data further give rise to new storage schemes and user interfaces that make NEES data accessible through common digital libraries.

NEEShub Platform

Nees.org is the web portal to all NEES information. Currently, visitors can get information about the NEES Equipment Sites, access archived data in the Project Warehouse, learn about the NEES community, download software tools, see an activity calendar, and find news items. We are developing a new platform that will add advanced capabilities to this web site, based on the successful HUB platform first implemented at nanohub.org [McLennan and Kennell, 2010], developed at Purdue University, and rooted in Purdue research [Park, et. al., 2000]. A key distinction of the new NEEShub is that users can activate software tools without download and installation. Thus, a user will be able to open a data viewer and inspect research data in the Project Warehouse, and plot sensor A versus sensor B while viewing the specimen in 3D. We are supporting such direct execution of all software tools that the NEES community has already

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developed. We are also developing additional data viewing capabilities. All of these new functionalities will be available for new data and tools, as well as data currently archived in the data repository and tools currently available at nees.org.

Direct web execution of tools at nees.org will take advantage of *data and tool co-location*. The actual tool execution platform is physically close to the data repository, allowing for fast data transfer. Thus, users will be able to inspect large data volumes without incurring excessive data transfer times, which has been raised as a concern in the previous environment. Launching simulation tools, such as OpenSees, on the NEEShub can also take advantage of the platform's connection to powerful high-performance computing resources. Thus, a user launching a computational simulation job on NEEShub can request that the job be executed on one of the U.S. National Science Foundation's TeraGrid platforms.

Conventional download of both software tools and data will continue to be supported. Users wanting to obtain a copy of all or selected data for a research project, such that they can analyze the data in detail on their local computer platform, can do so. Software tools can be downloaded and installed in conventional ways as well. This approach can be advantageous for tools that are used frequently and for users who do not have reliable broadband Internet access. Local installation may also be the choice for tools that must be connected to local resources, such as data acquisition hardware and local databases.

The NEEShub further provides a portal to the education, outreach and training (EOT) activities in the NEES network, referred to as the NEES Academy. EOT plans are described in a companion paper [Anagnos et al. 2010].

Design Principles

As we implement the new NEES cyberinfrastructure, we are applying several design principles. All software developments are strictly driven by community requirements. We are gathering user requirements through a number of channels, including a User's Forum that represents the NEES community. This process is followed by prioritization, also by the community. Another principle that we are using is the close collaboration between earthquake engineers and information technology experts in our software design process, which ensures that new cyberinfrastructure functionality presents interfaces that are convenient for the intended end-users. We further strive to apply best development practices for cyberinfrastructure [Kirsch and Slaughter, 2008], such as frequent prototypes and community feedback. Finally, as we recognize that similar cyberinfrastructure needs arise in other science communities, we aim to collaborate with such efforts, creating synergy that benefits all involved.

Conclusions

A new phase of the NEES project is making an effort to provide innovative cyberinfrastructure to the network, with the goal of integrating the geographically distributed NEES resources and the user community. We are creating the NEEShub, bringing advanced functionality to the

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existing web portal at nees.org. The new cyberinfrastructure aims to be more community-driven. Among the key issues is the management of research data. Improvements will come from co-location of data with supporting tools for analysis and visualization as well as from new data curation methods that can be used throughout a research project. Data Management is an increasingly important concern not just for NEES but also for many other domains of science and engineering. Creating synergy with these domains is another concern of the ongoing project.

Acknowledgement

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