CYBERINFRASTRUCTURE DEVELOPMENT FOR DESIGN AND TESTING OF NONSTRUCTURAL BUILDING COMPONENTS

Thuy T. Le[1], Syeda Naema Hashmi[2], and Kurt McMullin[3]

[1] *Professor, Electrical Engineering Dept., San Jose State University, San Jose, CA 95192, USA*
[2] *Graduate Student, Electrical Engineering Dept., San Jose State University, San Jose, CA 95192, USA*
[3] *Associate Professor, Civil Engineering Dept., San Jose State University, San Jose, CA 95192, USA*
Emails: Thuy.Le@sjsu.edu, s.naema@gmail.com, mcmullin@email.sjsu.edu

ABSTRACT

One aspect of the Pathways project is the development of cyberinfrastructure tools for use with nonstructural elements such as building façade systems and plumbing systems. The first cyberinfrastructure tool developed for the project is the "Synchronizer", a web-based application that is able to assist project members in data organization with NEES data repository. Synchronizer allows project members to connect to NEES data repository to download and upload data in bulk. The application automatically checks for updated files with options to replace, rename, or to keep them all. The application also allows the project administrator to put different restrictions to each project member in accessing the files and sub-directories. Synchronizer uses Mozilla Fire Fox for obtaining "GAsession ID" cookie and Internet Explorer for executing the application. The second tool that will be developed for the project is the "DataFinder." This tool will be able to perform data mining on NEES data repository and to provide user-friendly interface to practicing engineers and researchers for retrieving data in a suitable format. The application will have features to compare the retrieved material properties with selected material models available in the code, including the stress-strain relations and force-displacement responses. The development of Synchronizer application was completed and currently is under final testing. The development of DataFinder is in progress and expected to be completed in summer 2009.

KEYWORDS: NEES Data Repository, Stress-Strain Models, Force-Displacement Responses.

1. THE PATHWAYS PROJECT

The Pathways project [1] mainly addresses critical needs for the earthquake engineering community in providing quantified values for the force-displacement relationships of non-structural building systems including facades, plumbing and stairways. The data obtained from the project will allow building engineers to model performance of these systems in both existing and future building designs. Due to the development of the NEES repository [2-4], an archival bank of test data is widely available in a digital format. The data can be used to make accurate nonlinear spring elements in building software models, but there is a need to develop software that will locate suitable test data, identify the critical material and geometric properties of the test, massage the data into a form that replicates the geometry and material used in the current design, and translates that data into a digital format suitable for the analysis program being used. Moreover, due to the fact that several researchers at different locations working on the same project at the same time, there is a need for sharing and updating global and local data synchronously. The Pathways project includes the cyberinfrastructure component for the development of two software tools: The "Synchronizer" and the "DataFinder" applications.

The Synchronizer [5-6] has been developed to allow multi-user project members to update the data and information between the shared NEES repository and their individual local storages synchronously via a simple user-friendly interface. The DataFinder [7] will be developed for the Pathways project members to search for specified types of information on the NEES repository sub-domains, retrieve the selected test data in a simple format, and compare the data with available material properties models implemented in the application.

2. THE SYNCHRONIZER

Synchronizer is a web-based application developed to better help members of an earthquake related project in using the NEEScentral web portal. Synchronizer is helpful for projects that involved many members working at remote locations and the coordination of project data is complex. Synchronizer automates user connections to NEES repository in the way such that respective data can be uploaded and downloaded in bulk. The application automatically checks for updated files and users have options to either replace the old files with the new ones or to rename the old files and keep both of them. The application also allows the project administrator to set up different access restrictions to sub-directories and files on the NEEScentral account for each member of the project.

Since Synchronizer is a web-based application, the client (local computer) does not need to have any special software installed but the Internet Explorer for running the application and Mozilla Fire Fox for obtaining "GAsession ID" cookie. The initial version of Synchronizer has been developed based on standard model of web applications with HTML embedded scripting language PHP [8], MySql open-source database [9], GNU Wget [10], and Adobe Macromedia Dreamweaver web design and development tool [11]. Preliminary tests have shown that this model results in low performance and unreliable due to its communication protocol. With this reason, the current version of Synchronizer has been developed based on AJAX model with JAVA scripts [12].

2.1. Synchronizer Functionalities

Synchronizer can be installed and configured on any local web server (client server) or directly on the NEEScentral server. The installation location only makes a minor difference in the requirement of GAsession ID cookie. A user who wants to use Synchronizer needs to have a NEEScentral project account so that Synchronizer Administrator can configure restrictions on the file and directory accesses based on distinct association of a particular user with data stored on the NEES repository. This allows all researchers of one project working at remote locations to continuously and safely share and update the research results. The overall structure diagram and operation of Synchronizer is shown in figures 1 and 2 below:
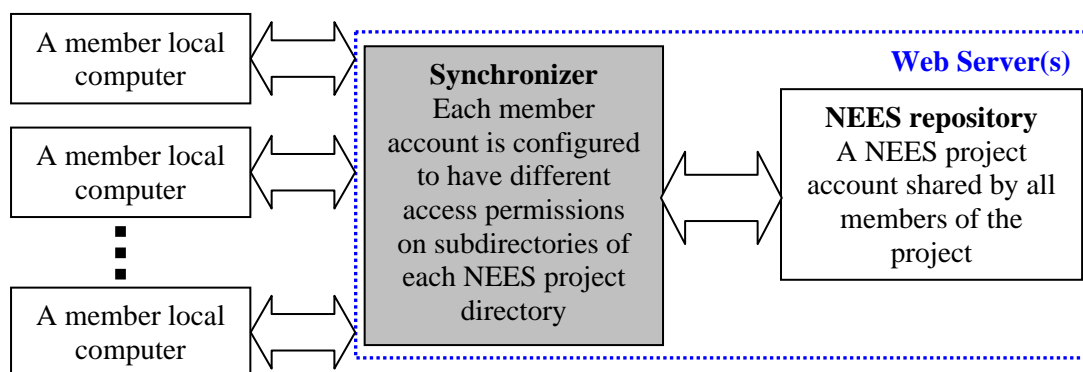

Figure 1 - Overall structure diagram of Synchronizer

Suppose that three researchers are working on the same project where the results from one researcher will be used by the other two whenever they are available. Since all there researchers are working at different locations, their common access point will be the "Project" account on NEEScentral where their results can be shared to each other. The three researchers can also share their research results to NEES community (who are not members of the project) by making their research results available in the "Public" folders. During the course of the project, all three researchers will be able to view all files in all subdirectories of the "Project" account. However, each researcher will have his/her own sub-directories for each level under the "Experiment and Simulation" level where they can continuously update their research results and use the results from other research members. When a researcher executes Synchronizer, his/her local data and results will be updated on

both the NEEScentral repository and on his/her local storage. The overall code activity of Synchronizer is described in Figure 3.
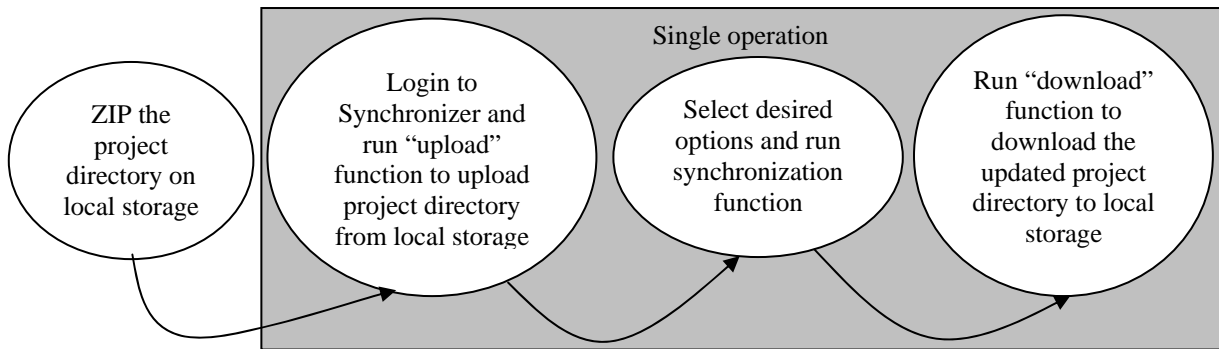

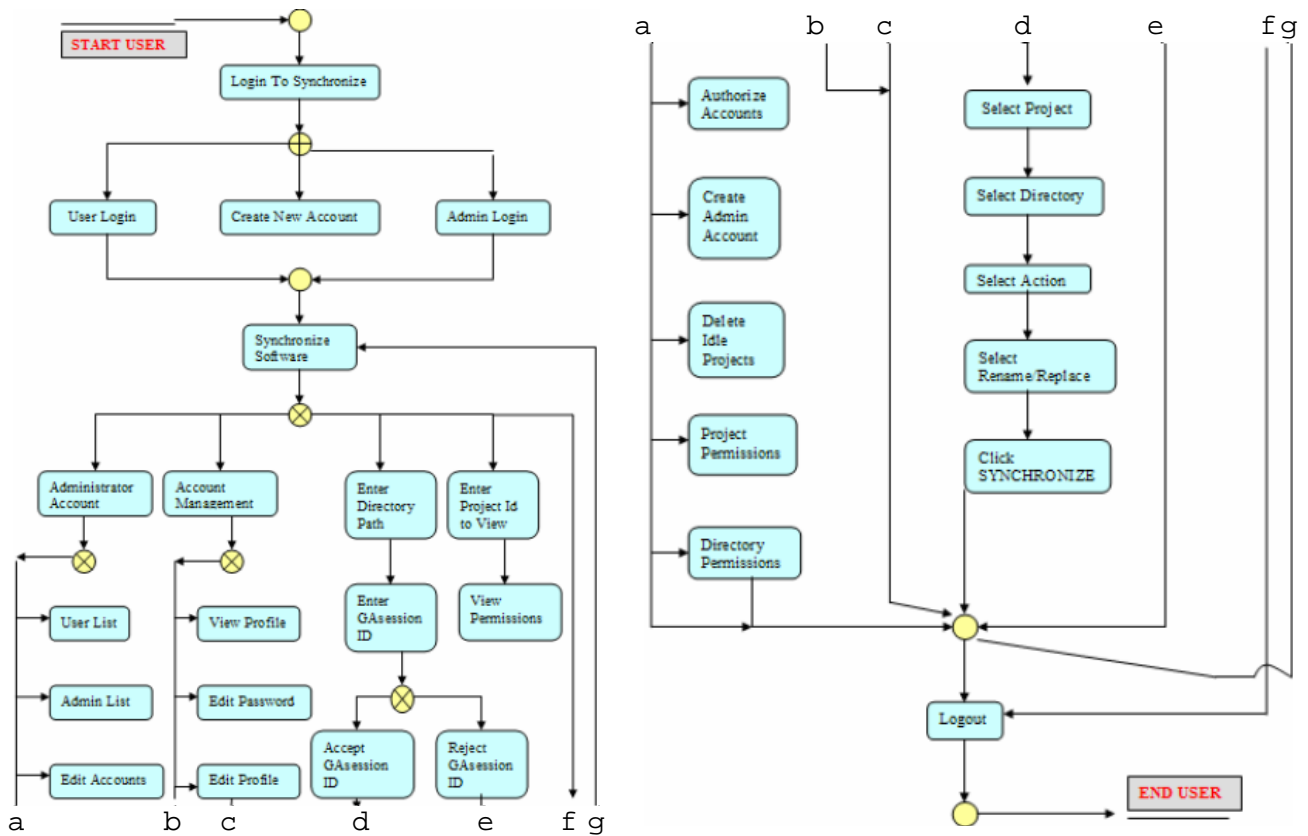Figure 2 - Overall operation diagram of Synchronizer

Figure 3 - Synchronizer activity model diagram

2.2. Code Structure of Synchronizer

The code structure of Synchronizer can be described by simplified functional code model diagram as shown in Figure 4. Synchronizer stores information by MySql database where four mandatory tables in the code are the "user" table, the "request_user" table, the "access_log" table, and the "project_list" table. The "user" table contains information of all current users. The "request_user" table contains information used to create user accounts. The "access_log" table contains information of all webpages accessed by the users. The "project_list" table contains information of all the projects on NEES repository that users of this project are affiliated with.

When a project is added into the database, Synchronizer automatically creates additional four tables for the new project. These four tables include a table for the "Experiment" directory, a table for the "Analysis" directory, a table for the "Document" directory, and a table for the "Public" directory. As an example, when a project ID "NEW" is added into the database, Synchronizer will create four tables named dir_exp_NEW, dir_ana_NEW, dir_doc_NEW, and dir_pub_NEW. Each of these tables contains information of all the subdirectories presented in that directory. The table also holds information regarding user permissions for uploading and downloading directory contents from these subdirectories. Subdirectories at lower levels are assumed to have same user permissions as of the parent directory above them.
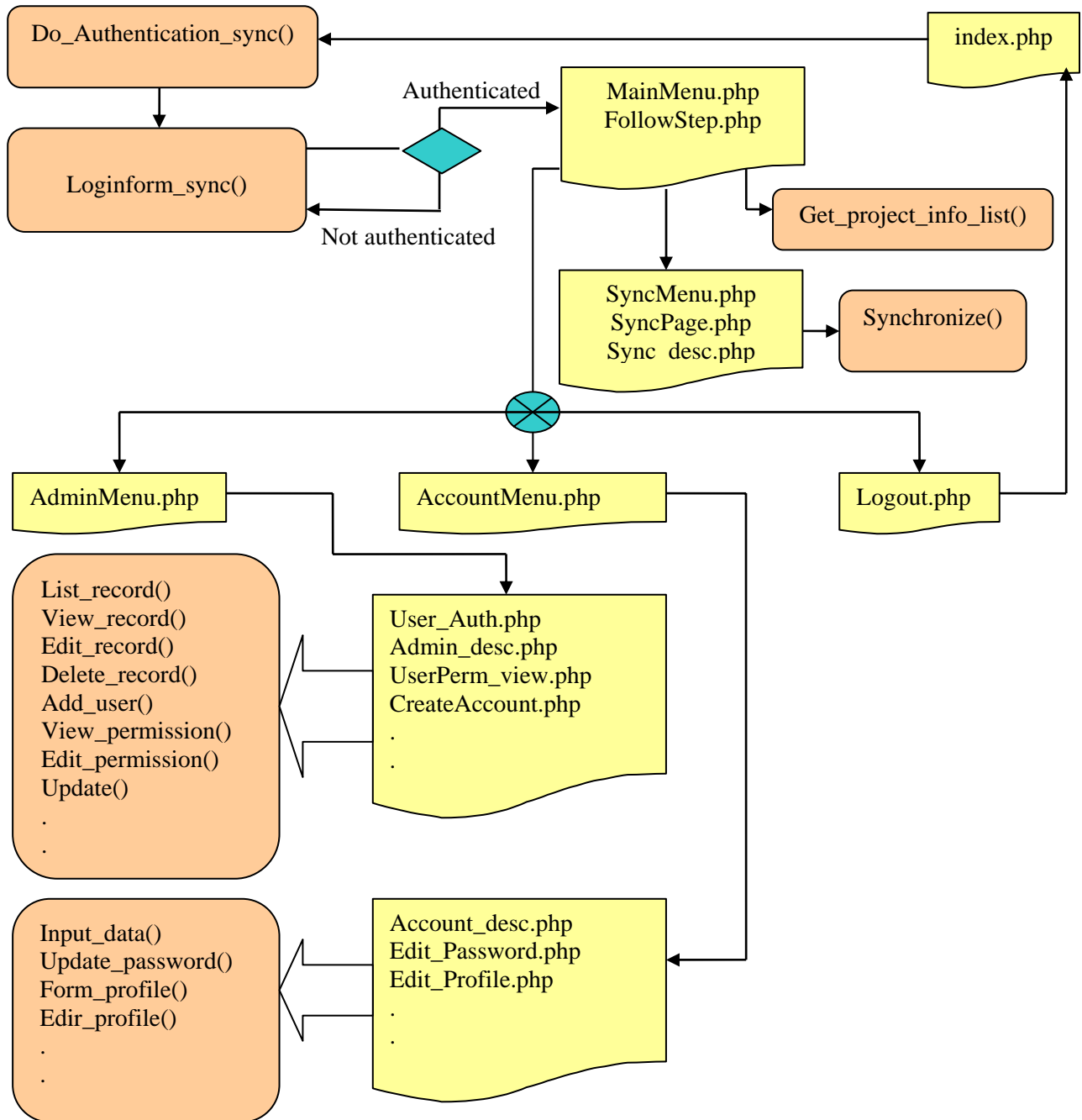
Figure 4 - Synchronizer data flow model block diagram

3. THE DATAFINDER

This tool performs data mining on NEES repository under user's specifications on the types of data to search for and the NEES sub-domains to search from. User specifications are performed via a user-friendly interface with selection drop-down and fill-in menus. The application will have features to compare the retrieved material properties with selected material models implemented in the code. The development of DataFinder is in progress and is expected to be completed in summer 2009.

3.1 Search Functions and Interfaces

Similarly to Synchronizer, DataFinder can be installed and configured on any local web server (client server) or directly on the NEEScentral server. The installation location only makes a minor difference in the requirement of GAsession ID cookie. The overall architecture of DataFinder can be represented by a 3-tier block diagram as shown in Figure 5.
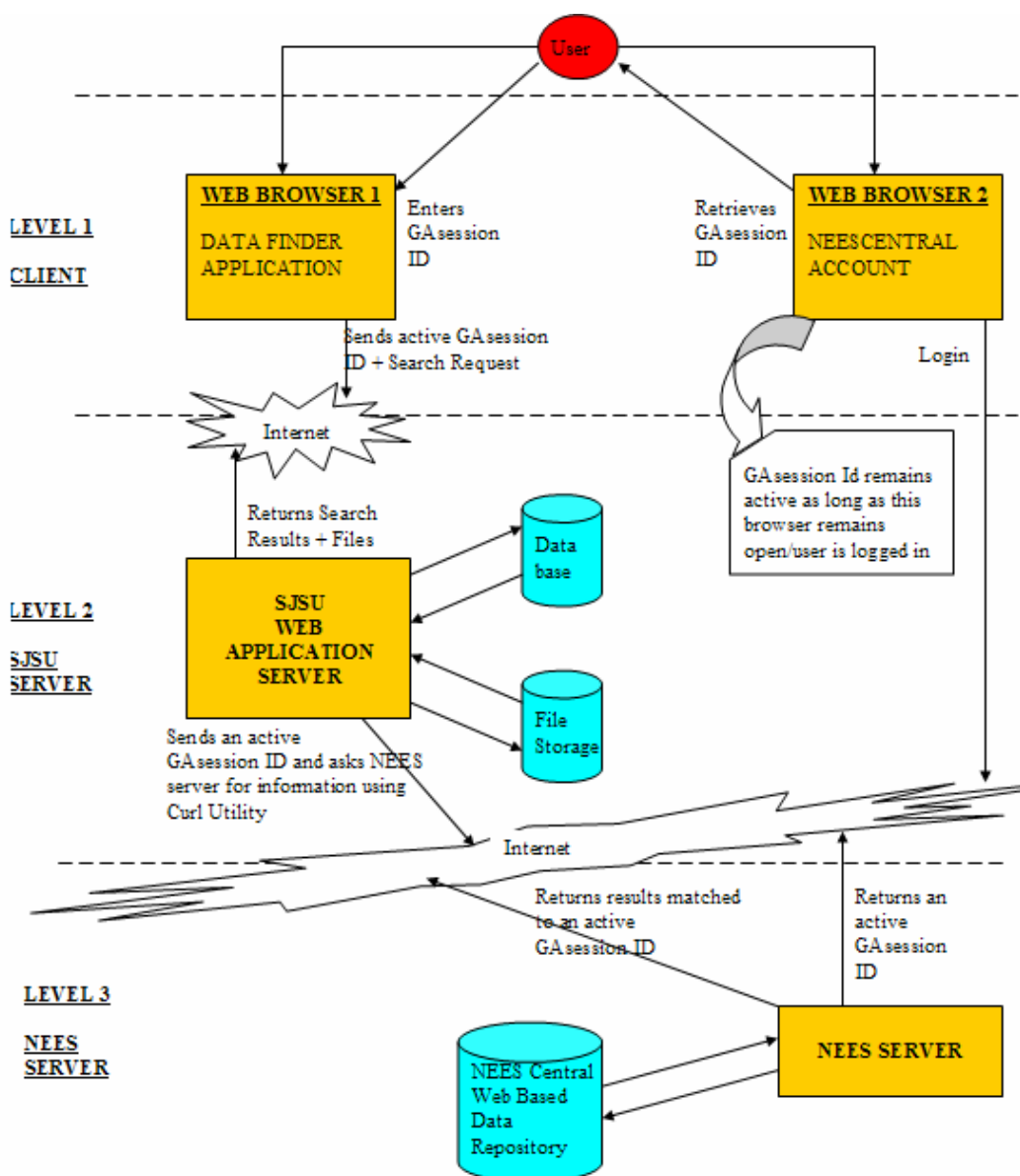

Figure 5 – Three-Tier architecture block diagram of DataFinder

A user who wants to use DataFinder needs to have a NEEScentral project account so that DataFinder can access NEES directories and files based on distinct association of a particular user with data stored on the NEES repository. The search engine allows users to specify the types of search data and the search domains at all levels on the NEES repository as shown in Figure 6. Depend on the domain levels specified by the users, DataFinder will return a list of links with explanations to direct the users to the NEEScentral browser to "Download" trial data, "Export Trial", "Export Experiment", "View Experiment Report", and/or "Export Project." Search parameter(s) can be a single term and/or multiple phrases with wildcards.

```
Search for Parameter(s) _____
Search under: "All Projects," "My Projects," etc.
·  Project domains include: Analysis (Y/N)? Documentation (Y/N)? Public
   (Y/N)?
·  Search parameter(s) must exist under Experiment(s) (Y/N)
   o  Experiment domains include: Analysis (Y/N)? Documentation (Y/N)?
      Data Viewers (Y/N)?
   o  Experiment setup includes
      ▪  Material name(s) _____
      ▪  Coordinate space(s) _____
   o  Search parameter(s) must exist under Trial(s) (Y/N)
      ▪  Trial domains include: Analysis (Y/N)? Documentation (Y/N)?
```

Figure 6 - DataFinder search specifications

The current design of DataFinder search functions is very much similar to the current NEEScentral search functions [13]. The development of the search options will be expanded during the course of the Pathways project in order to narrow down the specific data types and data locations required by the project.

3.2 Stress-Strain and Force-Displacement Models

Many materials have been used in the construction of buildings but our focuses for the Pathways project is on modern construction materials such as steels, woods, and non-structural materials for cladding and plumbing systems, etc. In structural analysis, the theories in mechanics of materials are used to relate the maximum stress and deflection of a structure member to the applied moment and shear as well as the member size and material stiffness. Moreover, the studies of the behavior of construction materials in terms of the stress-strain relationship determine the strength (or maximum stress capacity) and stiffness of the material and its failure mode. Due to the infrastructure decay problem in many developed countries, the long term performance of structures has become an important concern, which results in our interests of time-dependent problems of the stress-strain relationships. Tested and measured properties of many interested materials under different geometries, environments, conditions, ages of the materials, etc. are available on NEES repository. It would be useful if the data can be retrieved and used for other designs and calculations either directly or indirectly. Properties of interested materials in new geometries and designs can be derived by data interpolation or by numerical modeling where available test data on NEES repository is used as basic data points or initial parameters for a simulation problem.

3.2.1 Models of Stress Strain Relationship

Another function that will be implemented in DataFinder is the "Stress-Strain Model" function. This function allows the users to select the available material model implemented in the code and provide the required input parameters. The function also allows users to input test data from NEES repository as a completed set of data points of an experimental stress-strain curve. DataFinder will model the stress-strain relationship from the provided information and allows the users to generate additional property values per their requests. By sketching

a predicted material model together with test data from NEES repository of a certain experiment and/or trial, users can compare the theoretical material model with available test data and so can make their own decision on the use of material model and/or test data for their new designs.

As an example, a user uses DataFinder to locate a set of test data on NEES repository that closely matches the materials and geometry of the current design. By sketching the test data and mapping them to a theoretical model, DataFinder will provide the user with visual judgment for the accuracy of the predictive model and the usage of using the available test data for his/her current design. The available test data can be used directly in the current design or can be used to dictate the material model parameters in order to increase the accuracy of the selected model for the current design. The initial version of DataFinder is planned to support material models as listed below:

· Elastic material model
· Bilinear steel model
· Menegotto-Pinto steel model [14-15]
· Monti-Nutti steel model [15]
· Superelastic shape-memory alloys model [16]
· Trilinear FRP model
· etc.

3.2.2   Models of Force Displacement Response

Another function that will be implemented in DataFinder is the "Force-Displacement Response" function. This function allows the users to select the available force-displacement model implement in the application and provide the required input data for the model. DataFinder can model the force-displacement relationship for all six degrees-of-freedom and compare the model response curve with available test data points on NEES repository. Users can use the available test data to instruct the software to justify the model parameters per their judgments. The accuracy of force-displacement models is critical for accurate computer simulation of the post-elastic behavior of the structures during an earthquake followed by the probabilistic prediction of possible damage and repair cost of the nonstructural elements of the buildings. Although the Pathways project concentrates on force-displacement relationships of non-structural elements such as rod-type push-pull connections, cantilever bearing connections, steel-plate lateral support connections, etc., the "Force-Displacement Response" function will be initially implemented based on general link elements. The initial version of DataFinder is planned to support the response models as shown below:

· Linear symmetric and asymmetric
· Bilinear symmetric and asymmetric
· Trilinear symmetric and asymmetric
· Nonlinear elastic and Plastic [17]
· Simplified bilinear Takeda, Osgood, etc. [17-18].

4.   **CONCLUSION**

The initial development of a web-based application named Synchronizer to enhance the capability of the NEEScentral Web Portal has been completed. Synchronizer has been proven to be useful in assisting researchers of multi-member projects in organizing and sharing local data with NEES data repository frequently. The idea of synchronizing data files stored on different data storages is not new and there are quite a number of file transfer software tools that have similar functions and abilities. The development of this software is however for a specific data storage structure where different levels of file synchronization is applied to different files categories and file owners located at the same remote storage allocation. It should be noted that Synchronizer is able to synchronize the work of multi-researchers as well as to synchronize data files stored on local and remote storages.

The development of DataFinder is still in progress and is expected to be completed in summer 2009. This tool performs data mining on NEES repository under user's specifications on the types of data to search for and the

NEES sub-domains to search from. The application will have features to compare the retrieved experimental data stored on NEES repository with selected material models implemented in the code. Property models implemented in DataFinder will include "Stress-Strain" models and "Force-Displacement" response models. The implementation of different theoretical models will be based on the needs of the Pathways project.

5. ACKNOWLEDGEMENT

REFERENCES

[1] The Pathways Project. http://www.engr.sjsu.edu/pathway/.
[2] Network for Earthquake Engineering Simulation – A Special Report. *National Science Foundation*. www.nsf.gov/news/special_reports/nees/about.jsp.
[3] NEES Consortium Development Project. *Consortium of Universities for Research in Earthquake Engineering*. www.curee.org/projects/NEES/index.html.
[4] NEEScentral. https://central.nees.org/.
[5] Synchronizer. http://www.engr.sjsu.edu/~pathway/Synchronizer/.
[6] Thuy T. Le, Syeda Naema Hashmi, and Kurt McMullin. (2008). Synchronizer - A Web-based Application to Enhance Capabilities of NEESCentral Web Portal. *Proceedings of the 7th IEEE/ACIS International Conference on Computer and Information Science* (ICIS 2008).
[7] DataFinder (under-development). http://www.engr.sjsu.edu/~pathway/DataSearch/.
[8] PHP: Hypertext Preprocessor. http://www.php.net/.
[9] MySql Open-source Database. http://www.mysql.com/.
[10] GNU Operating System. http://www.gnu.org/software/wget/.
[11] Adobe Macromedia Dreamweaver. http://www.adobe.com/products/dreamweaver/.
[12] Garrett, J. (2005). AJAX: A New Approach to Web Applications. http://www.adaptivepath.com/publications/essays/archives/000385.php.
[13] NEEScentral Advance Search. https://central.nees.org/?action=AdvancedSearch.
[14] Monti, G. and Nuti, C. (1992). Nonlinear Cyclic Behavior of Reinforcing Bars Including Buckling. *Journal of Structural Engineering*, **Vol. 118, No. 12**, pp. 3268-3284.
[15] Monti, G., Nuti, C. and Santini, S. (1996). CYRUS - Cyclic Response of Upgraded Sections. *Report No. 96-2*, University of Chieti, Italy.
[16] Auricchio, F. and Sacco, E. (1997). A Super-elastic Shape-memory-alloy Beam. *Journal of Intelligent Materials and Structures*, **vol. 8**, pg. 489-501.
[17] Otani, S. (1981). Hysteresis Models of Reinforced Concrete for earthquake Response Analysis. *Journal of Faculty of Engineering*, University of Tokyo, **Vol XXXVI, No2**, 1981 pp 407-441.
[18] Emori, K. and Schnobrich, W.C. (1978). Analysis of Reinforced Concrete Frame-Wall Structures for Strong Motion Earthquakes, *Structural Research Series* **No. 434**, Civil Engineering Studies, University of Illinois at Urbana-Champaign.