구조실험을 위한 데이터 모델의 개발

Development of Data Model for Structural Tests

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ABSTRACT

Structural tests often involve a large amount of complicated information. Data models can be used to efficiently organize the information. This paper briefly describes a data model for structural tests including hybrid tests, performed by the Real-Time Multi-Directional (RTMD) facility at the ATLSS Center of Lehigh University in America. The RTMD facility is an equipment site within the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES). The data model is called the Lehigh Model. An overview of classes and attributes of the Lehigh Model is presented, and the Lehigh Model is compared with other data models to show its benefits for structural testing.

Keywords: *data model, structural test, hybrid test, information.*

1. Introduction

Structural researchers perform laboratory tests to examine and understand the behavior of structural components, connections, and assemblies and to develop ways of enhancing this behavior. A data model helps researchers logically organize and manage the information and data from structural tests using predefined hierarchies and categories of information. Several research efforts to develop data models for earthquake research have been undertaken in support of the George E. Brown Jr. Network for Earthquake Engineering Simulation (NEES), which is a shared national network of 15 experimental facilities in the United States, linked by NEES information technologies (NESSit, 2006). The Reference NEESgrid Model (Peng and Law, 2004) is designed to represent shaking table test data, but many aspects of the model are relevant for other types of structural tests. The Oregon State Model (Oregon State University and Network Alliance for Computational Science and Engineering, 2003) represents test data from tsunami wave basin experiments. The NEEScentral Model (NEESit, 2006) is developed for NEES to provide to represent information for structural and other earthquake engineering experiments. The implementation of this data model is intended to be an application that allows users to store and retrieve the test data via the internet. Based on the previous work on the data models and studies of a number of experimental projects conducted at the Real-Time Multi-Directional (RTMD) testing facilities at the ATLSS Center of Lehigh University, a data model has been developed to describe large-scale structural experiments (Lee et al., 2006). The data model is called the Lehigh Model. The Lehigh Model

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includes a number of classes and attributes. This paper provides the overview of the classes and attributes of the Lehigh Model, compares with other data models, and discusses the benefits of the Lehigh Model to represent the information related with structural experiments.

2. Notation for Classes and Attributes of Lehigh Model

The main classes and attributes of the Lehigh Model are shown in Figure 1. They are represented using a modified entity-relationship diagram developed for entity-based integrated product and process models (Hong and Sause, 1994). Each rectangle in the figure indicates an entity category (referred as a class). Each attribute of the classes shown below the rectangle with a horizontal bar. If the attribute is single-valued, the bar ends with an empty circle, and if the attribute is multi-valued, the bar ends with a black circle. The value set of an attribute (the set of possible values for the attribute) is represented in square brackets. The attribute type is identified in parentheses. The attribute of a class is classified into two main types: (1) "data-valued" attributes (DVA) whose values are alphanumeric or indecomposable and (2) "object entity-valued" attributes (OEVA) whose values refer to other classes. Further classifications of the attributes include based attributes (B), internally derived attributes (DI), and externally derived attributes (DE). Some of these attribute types are used in Figure 1.

3. Overview of Classes and Attributes of Lehigh Model

The Lehigh Model shown in Figure 1 presents an overview of the main classes and some of their attributes. The project class includes the experimental tasks attribute and the analysis tasks attribute. These attributes are multi-valued and they represent the multiple experiment tasks and analysis tasks, respectively, that will compose a typical large-scale research program. The value set of the experimental tasks attribute refers to the experimental task class which is the generalization of the typical experimental task class and the hybrid experimental task class. The typical experimental task class is for the typical types of experiments conducted at the RTMD facility, including pseudo-dynamic experiments, and the hybrid experimental task class for the hybrid experiments including hybrid pseudo-dynamic experiments.

The typical experimental task class includes a number of test conditions. Each of the test conditions is associated with a unique set of test data. The test condition class includes the attributes for the specimen, facility, loading fixtures, and bracing and reaction fixtures. A specimen, a facility, a number of loading fixtures, and a number of bracing and reaction fixtures are used for defining a test condition. Other factors not shown in Figure 1 are also used for a test condition. If any of the associated attribute values vary, then a new test condition is defined. The test condition class also includes tests and analyses. For a given test condition, multiple numbers of tests and analyses can be performed. The test class includes attributes for the test protocol that defines the loading protocol, any uncontrolled test conditions, for example, the temperature, and the resulting data set including the generated raw data and other data.

The hybrid experimental task class includes a simulation coordinator, a number of analytical substructures, and a number of physical substructures. In hybrid tests, the physical substructures are the parts of the structure that are simulated in the laboratory, so the physical substructure class is similar to the test condition class and the physical substructure test class is similar to the test class.

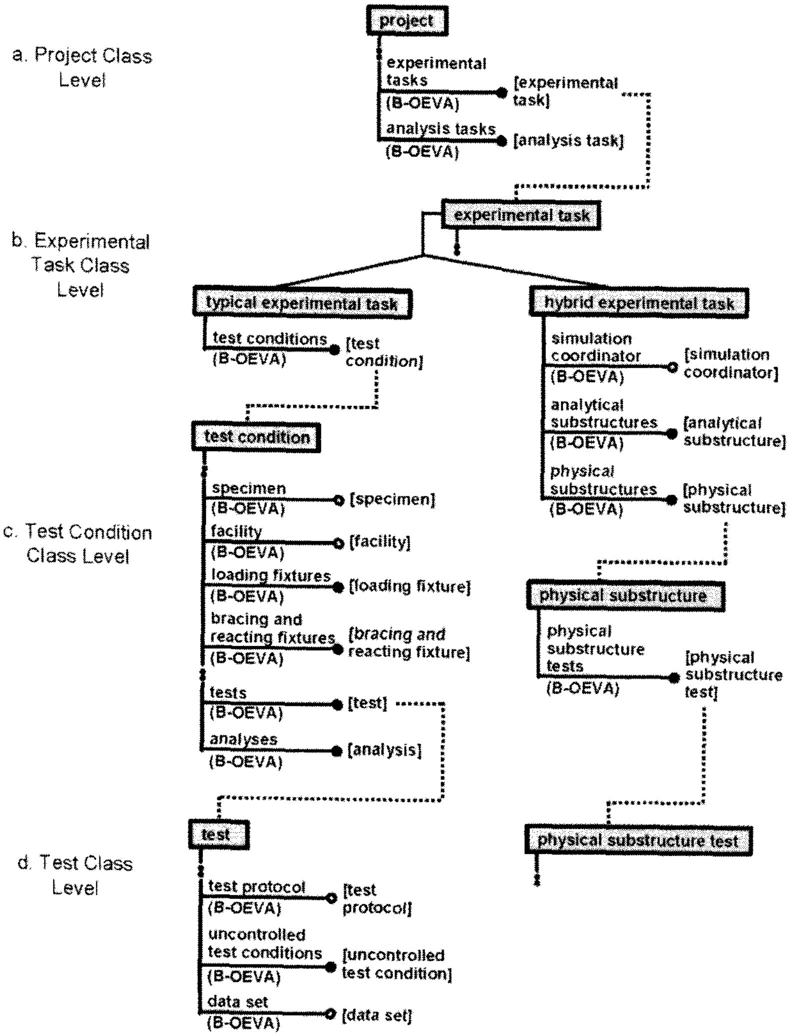

Figure 1. Overview of Classes and Attributes of Lehigh Model

4. Comparison of Data Models for Structural Tests

Figure 2 compares the Lehigh Model with the NEEScentral Model (NEESit, 2006), the Stanford Model (The Reference NEESgrid Data Model: Peng and Law, 2004), and the Oregon State Model (Oregon State University, 2003). The same notation is used for representing main the classes and attributes of the data models. Due to the abbreviated nature of this summary, the attribute types are not included in the discussion. Brief explanations for each data model are as follows:

(1) Lehigh Model (Figure 2a): A project includes multiple numbers of experimental tasks and analysis tasks. An experimental task may be a typical experimental task or a hybrid experimental task. Each typical experimental task includes a number of test conditions at different sites. For a test condition, multiple numbers of tests and analyses can be performed. Each test includes the attributes for the test protocol, uncontrolled test conditions, and data set.

(2) NEEScentral Model (Figure 2b): A project includes a number of experiments or simulations. Each experiment has its own experimental setup and includes a number of trials. Each trial has different input motions and generates a number of test data sets.

(3) Stanford Model (Figure 2c): A project includes a number of tasks which can be single site tasks or multi-site tasks. For the same infrastructure, a number of event groups can be performed. Each event group has its own setup and includes a number of events. Each event has its own software setup and output data.

(4) Oregon State Model (Figure 2d): A project includes a number of experiments. An experiment is carried out at a facility and has a number of configurations. Each configuration has its own equipment configuration and a number of trials which include the output.

5. Comparison of Organizations of Data Models

The data models shown in Figures 2a to 2d have levels of class hierarchies from the top level classes to the lower level classes. When the lowest level classes are considered to be the classes that include the test data, the main classes of the data models are as follows:

(1) Lehigh Model: project - experimental task - test condition - test

(2) NEEScentral Model: project - experiment or simulation - trial or run

(3) Stanford Model: project - task - event group - event

(4) Oregon State Model: project - experiment - configuration

For all data models, the project class is the top level class. Each model uses different definitions of the lower level classes. The Lehigh Model defines the experimental task class which includes a number of test conditions. The NEEScentral Model, the Stanford Model and the Oregon State Model define experiments or tasks related with the organizations or the facilities. The test condition class in the Lehigh Model includes the attributes for the setup of the specimen and equipments. The test condition class corresponds to the experiment class in the NEEScentral Model, the event group class in the Stanford Model, and the configuration class in the Oregon State Model. The test class in the Lehigh Model is similar to the trial class in the NEEScentral Model and the event class in the Stanford Model.

6. Benefits of Lehigh Model

From the overview of classes and attributes shown in Figure 1 and the comparison with other data models shown in Figure 2, the Lehigh Model has the following differences and benefits for large scale structure experimental projects:

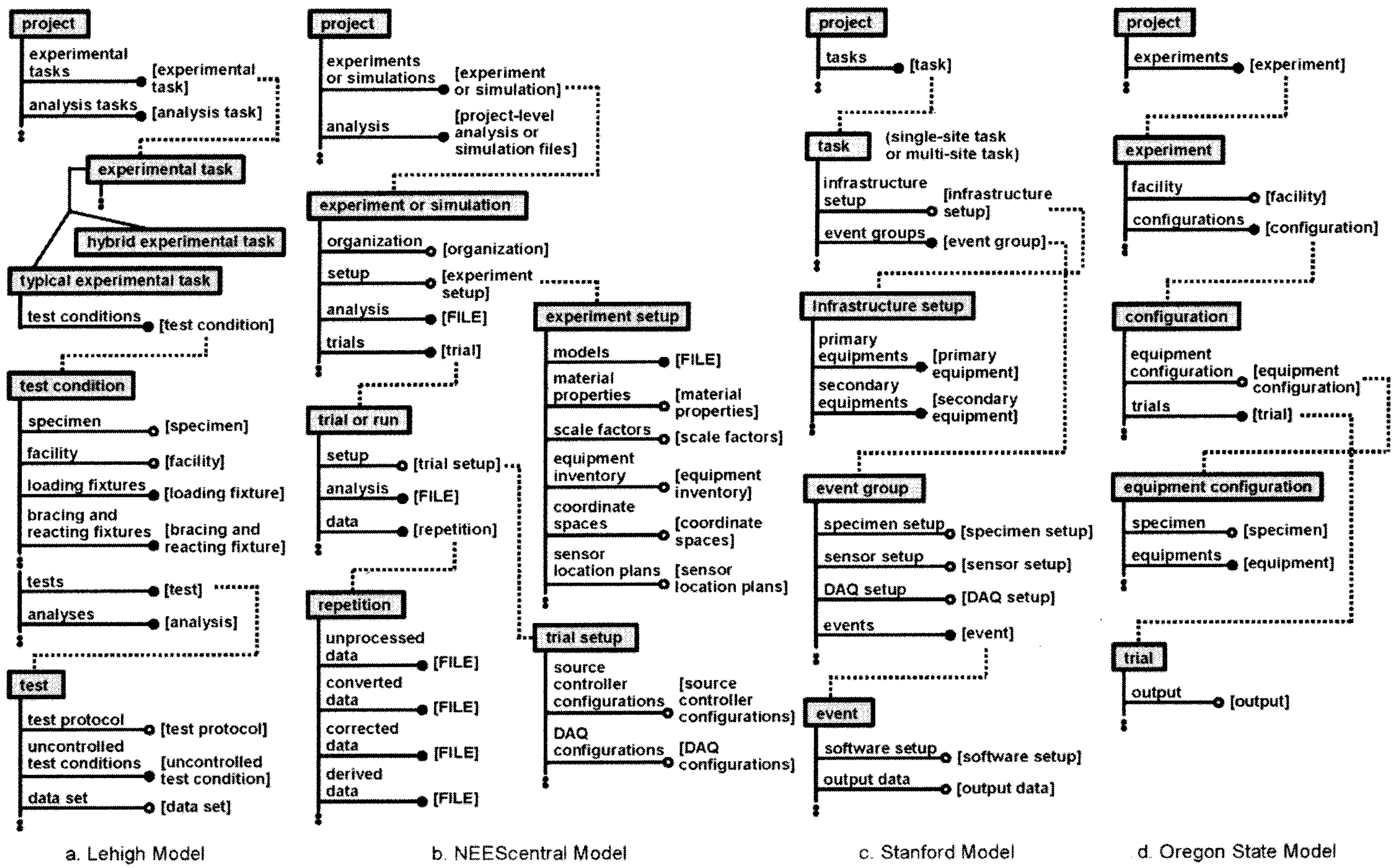

Figure 2. Comparison of Data Models for Structural Tests

(1) In the Lehigh Model, an experimental task is independent from a particular facility and can be related with multiple facilities, while in the other data models this level always related with a specified organization or facility. Other data models need to combine single-site tasks to describe a multi-site task. The Lehigh Model can provide a simpler and more flexible way to describe experimental tasks regardless of where the tasks are carried out.

(2) The Lehigh Model emphasizes the description of the test condition, which is usually complex in large-scale structural experiments. The test condition class is intended to provide a more detailed description of the specimen, facility, and equipment (loading fixtures and bracing and reaction fixtures) and the relationships among these things including the specimen components and the locations of the specimen components and equipment at the facility.

(3) The Lehigh Model enables the description of hybrid experimental tasks that other data models have not addressed. The Lehigh Model represents the communications among the simulation coordinator, analytical substructures, and physical substructures (not shown in detail in Figures 1 or 2).

(4) The test class in the Lehigh Model includes uncontrolled test conditions to describe the other conditions which are not controlled but may affect the test results. Examples may include temperature, humidity, and other environmental condition.

7. Concluding Remarks

This paper has described an overview of the Lehigh Model for structural tests developed by the RTMD facility at the ATLSS Center of Lehigh University. The model enables the complexity involved in structural tests, particularly that in hybrid tests, to be represented and has explored the areas that other data models have not addressed to date. The Lehigh Model is being expanded and implemented and is expected to provide an improved data model for structural tests.

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