ONTHOLOGY-BASED INTEGRATED ENVIRONMENT FOR EARTHQUAKE ANALYSIS AND DESIGN

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ABSTRACT

Large volumes of earthquake damage data have been collected over the past fifty years with the help of rapid development and advances in technology, such as satellites, GPS and GIS, combined with organized field reconnaissance and damage surveys following destructive earthquakes. Furthermore, a substantial body of knowledge has been accumulated over the past couple of decades from experimental testing of building components and systems. Ever since the 1971 San Fernando, California earthquake, a substantial amount of recorded earthquake response data has been collected from instrumented buildings and facilities. This huge collection of recorded response data is from instrumented buildings that have gone through multiple earthquake events. Such building response recorded data, combined with observed building damage and performance data from previous earthquakes, provide a substantial knowledge base of information from which we can derive lessons by developing intelligent tools for seismic hazard assessment of a broad class of buildings not only in the U.S. but around the globe. This large body of knowledge provides a context for future engineering activities. This paper proposes the creation of an earthquake ontology, which will integrate many data sources to present a larger picture for researchers, designers, policy makers and other types of users. The ontology will help turn the large volume of data into knowledge by connecting different data items from different sources and providing basic rules of inference to expand the knowledge, provide means to check the validity of some data, and to fill-in some of the missing information. The integrated environment will encompass data translators, which will access the variety of data sources and translate the data into the adequate ontology format. Data analysis tools will help determine the place of each data item in the ontology and resolve redundant information. The ontology environment will enable the creation of intelligent tools for seismic analysis and design of structures. These tools will encode the standard rules of practice using the ontology as the main description for the design objects. The proposed environment can be adapted in many ways to support specialized effort. For example, the preservation of historical structures can benefit from this environment by developing intelligent agents that focus on the issues of preservation and hazard mitigation for historical structures. The benefits of the integrated environment extend to research, regulations, policy and teaching.

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Data Types and Existing Data Sources

Earthquake events generate large volumes of data, which can be beneficial to many types of users [1]. Two main types of data are generated: 1) recorded data, such as ground motion, building response and bridge recording data, and 2) observed damage data, such as patterns of structural damage, exterior damage to facades and claddings, and mechanical, electrical and plumbing (MEP) systems, etc. Different types of data are maintained by different organizations, in different formats and have different access methods.

Recorded Data for Earthquake Events

Ground Response Data (GrRD): recorded data from recording stations consists of time-history data of ground displacements, velocity & acceleration, as well as ground response spectra.

Building Response Data (BuRD): recorded data from recording stations consists of time-history response data of displacements, velocity & acceleration, as well as response spectra at the ground level and at different levels in the instrumented buildings.

Bridge Recording Station (BrRS) Data: recorded data from recording stations consists of time-history response data of displacements, velocity & acceleration, as well as response spectra at the ground level, superstructure level, and at the piers and abutments in the instrumented bridge structures.

Observed Damage Data

Observed damage data obtained from field reconnaissance following disastrous earthquakes is found to be scattered across multiple agencies, departments and sites. Depending on the nature of the earthquake event, the damage data is collected for a broad class of building types, bridge structures, and dams, to compile patterns & distribution of observed damage. For different building types, the damage data may be classified into the following categories:

- **Building type, age & configuration.** These include description of building e.g. low-rise, medium-rise, high-rise; material; age of construction; and form & configuration including plan and elevation irregularities.

- **Structural framing system including foundation systems.**
  This includes a description of the gravity load & lateral load resisting system; the respective materials, as well as the foundation system.

- **Patterns of structural damage.** These may include damage to the primary structural system members; the types of damage & their distribution across the building system.

- **Interior architectural systems.** Based on experience during the past several decades, observed damage to architectural systems has become an important part of the overall earthquake hazard & loss mitigation. Observed damage may include damage to interior partition & ceiling systems; lighting systems; including the types of damage and their distribution across the building.

- **Exterior architectural systems e.g. facades /cladding.** Observed damage may include damage to exterior enclosure /envelope / façade/ cladding systems, including types of damage & their overall distribution.

- **MEP systems.** As MEP systems constitute a significant part of the overall cost of a building, the mitigation of hazard & damages to these systems is considered a very important issue.
Observed damage may include damage to mechanical & electrical equipment, air-conditioning, plumbing, and fire protection systems

- **Contents.** This issue is extremely important in heritage buildings e.g. museums with their priceless art collections; warehouse type of stores; hospitals, libraries, laboratories. With increasing reliance on information technology in all sectors of a nation’s economy, the mitigation of damage to IT equipment is crucial for survival and recovery following an earthquake event.

For bridge infrastructure systems the damage data may be classified into the following categories:

- Bridge type, age & configuration
- Bridge layout and structural framing system. This may include the overall layout of the bridge structure, description of the bridge structural framing system including the foundation system
- Patterns of structural damage to sub-structure system, e.g. the bridge foundation system
- Patterns of structural damage to super-structure system
- Patterns of damage to pier & abutment system

**Ontology Integration Approach**

An ontology is a structure of knowledge in a domain, which captures the significant objects in the domain and the relationships that connect objects [3]. It provides a perspective for understanding the domain and explore multiple views of how objects in the domain may behave. An ontology is structured in a logical way, which provides the opportunity to perform reasoning on the existing objects and produce more knowledge out of the existing objects and relationships [4, 5]. The reasoning capabilities of an ontology allow for intelligent agents to perform high level tasks of examining the environment and suggesting actions that are appropriate to the current state of objects.

**Design of the Integrated System**

This project aims to build an integrated view of multiple data sources in the area of earthquake engineering and make the data more manageable and available on-demand from multiple perspectives.

The proposed system consists of three layers: data extraction layer, information model layer, and data access layer. The system is designed in a Service-Oriented Architecture which provides benefits for scalability, high availability, easy access, and easy integration into other applications. Figure 1 shows the overall architecture of the proposed systems.

![Figure 1. System Architecture](image)
Types of Users

The integrated system can be used by many types of users for different purposes. Designers, architects and engineers can benefit from building type information and knowledge of regulations to produce a plan for assessing a given damaged structure. Restoration efforts rely on such plans for making decision about priorities of work and estimates of cost.

Planners, building officials and policy makers can use the system to examine existing policies, and develop more effective and responsive policies and hazard mitigation plans.

Government agencies and organizations benefit by having an access to a bigger picture of any given hazardous event and its impact on its affected areas. This view allows for a more efficient resource allocation to mitigation efforts.

Researchers benefit from the proposed system by having ready access to integrated information about structures, which are affected by earthquake events, including the site effects, building information, codes and regulations, and effects of hazards. The integrated environment allows researchers to navigate the existing information and gain insight of the effect of the different events on different types of structures.

Conclusions

The advancements in information technology has led to an explosion of data in many fields, including earthquake engineering. We presented the current state of earthquake data availability and noted the need to integrate multiple data sources into a contextual ontology, which will help practitioners, policy makers, emergency responders and other types of users make better decisions and plans. We proposed a system to integrate the data sources and provide the user with tools to interact with the ontology in many ways. The system is designed in a service oriented architecture, which will allow for addition of services and expansion of functionality as new needs emerge.

References