NHERI@UCSD: Tools for Shake Table Users

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Outline

- **Shake table simulation and input motion generation tools**
- **Instrumentation**
  - Sensor Inventory and DAQ System
- **Tele-presence and Video Recording System**
  - Camera Inventory
  - Site Drones
- **Live Video Streaming Capabilities**
  - WireCast System
  - DaCast service for zero latency live video streaming
- **IT Infrastructure**
  - Visible and invisible IT networks
- **Our Websites and Social Media Presence**
  - Resources for Researchers
Shake Table Simulation and Input Motion Generation Tools

Two different types of tools can be provided

1) Shake Table Simulation Tools
   ✓ For pre-test evaluations and checks

2) Input Motion Generation Tools
   ✓ For performing actual dynamic tests on the shake table using the motions generated by these tools
(1) Shake Table Simulation Tools

a. Forward Simulation Tool
   • Pre-test studies using the real controller and a validated model of the shake table
     ✓ The forward model is like the real system (i.e., when servo-valves are commanded, table motion results)

b. Inverse Simulation Tool
   • Checking the suitability of ground motions to be reproduced on the table in term of the table’s physical limits (e.g., disp., force etc.)
     ✓ In the inverse model, cause and effect are reversed (i.e., the system motion is input to the model, servo-valve openings result)
The forward model can be used for:

- Evaluating signal tracking performance
- Offline tuning of the controller

PC Simulation Mode

- The forward model can be used for:
  - Evaluating signal tracking performance
  - Offline tuning of the controller
Shake Table Forward Simulation Tool
Forward Model can be enhanced by using an extensive dynamic library.

- **Prime Movers**
  - Force
  - Displacement
  - Velocity
  - Pressures
  - Flow
  - Aux

- **1-DOF Payloads**
  - Displacement
  - Velocity
  - Acceleration
  - Force
  - Pressures
  - Flow
  - Aux

- **6-DOF Payloads**
  - Displacement
  - Velocity
  - Acceleration
  - Force
  - Pressures
  - Flow
  - Aux

- **Integrators**
  - 2nd-order lowpass filter
  - 1st-order lowpass filter
  - Second-order fractional delay

- **Differentiators**
  - Euler derivative
  - Bilinear derivative

- **Miscellaneous**
  - HP output
  - Integer delay
  - Fractional delay
Shake Table Inverse Simulation Tool

- Allows the user to take a desired motion profile (uni- or tri-axial) and
- Verify that the system can meet the demands in terms of displacement, velocity, acceleration, force, oil flow and pressure.
(2) Input Motion Generation Tools

- These tools are needed for
  - Input ground motion preparations for shake table testing
    - Ramp function, sine-sweep, sine-beat, random time histories
    - Pseudo-random THs
    - Response spectrum compatible THs
    - Base-line correction of THs
• We want to make sure that a smooth displacement ramp waveform is generated which has smooth and predictable maximum velocity, acceleration, and jerk (3rd time derivative of displacement).
Input Motion Generation Tools

Square/Triangle/Sine THs

- When we want to generate a periodic function,
  - Make sure that beginnings and ends must be tapered

![Graph of Square Time History with Scale Taper](image1)

![Graph of Square Time History with Append Taper](image2)

![Graph of Triangle Time History with Scale Taper](image3)

![Graph of Triangle Time History with Append Taper](image4)

![Graph of Sine Time History with Scale Taper](image5)

![Graph of Sine Time History with Append Taper](image6)

![Graph of Sine Time History with Spline Taper](image7)
Input Motion Generation Tools

**Sine Sweep THs**

- Sweep can be linear or logarithmic
- Taper up and down can be specified
- Taper shape can be linear, haversine or spline
Input Motion Generation Tools

**Sine Beat THs**

- Number of **beats**
- Number of **cycles** per beat
- **Pause** between beats in sec can be specified
• Creating a non-repeating random TH by passing uniform WN through a filter with desired spectral shape and bandwidth
Input Motion Generation Tools

**Pseudo-random THs with Desired Spectral Density**

- A different version of this tool can also be used for generating response spectrum compatible acceleration THs.
Input Motion Generation Tools

**Compressing Dynamic Range of THs**

- The **compressed signal** still has the **desired RMS amplitude** and **flat magnitude response spectrum**.
Input Motion Generation Tools

**Baseline Correction**

- Modifies acceleration records so that it **begins and ends at zero displacement, velocity, and acceleration** by series of operations
  - High-pass/low-pass filtering, detrending, padding the beginning and end with zeros
Instrumentation

The instrumentation inventory consists of:

- **200** MEMS type accelerometers
  - +/- 5g – DC to 200 Hz – Sensitivity 200mV/g
- **180** linear potentiometers (ranging 2 in to 20 in)
- **135** string potentiometers (ranging 2 in to 60 in)
- **10** spring potentiometers (range 1 in)
- **24** load cells (up to 20,000 lbs)
- **32** soil pressure transducers
- Load jacks (various)
- **1** GPS system with a network of antennae (two mobile and one reference), provides dynamic displacement monitoring in three coordinates, operates at 50 Hz

All sensors are calibrated (accredited in-house calibration is available)!
Instrumentation
Data Acquisition System

- **12** Data acquisition nodes (a distributed system) with **64 channels** and **16-bit** resolution each (total of **768 channels**)
- **7** are in active use now (total of **448 channels**)
- Each channel can be configured to accept **any type of sensor** (strain gauges, displacement transducers, accelerometers, pressure cells, load cells, etc.)

![Data Acquisition System Components]

- PXI 1050 Chassis
- PXI 8184 Controller
- SXCI 1520 Modules with TBs
- PXI 6251 DAQ
Telepresence/Video Recording System

- **Axis P1365 (3 Cameras)**
  - Provide delay-time viewing via web site
  - Provide *time-lapse* for projects
- **IDVR-Pro H.264 HD CCTV DVR (32 Coax)**
  - Trigger-based recording for synchronization with data
  - 16 channels of digital video recording with immediate playback capabilities *(synchronized with data)*
- **NUUO Hybrid Video Recorder/IP NVR**
  - Trigger-based recording for synchronization with data
  - 16 channels of digital video recording with immediate playback capabilities *(synchronized with data)*
Coax Cams
1080p HD

- 32 Coax Cameras
GoPro Cameras

- We have **15 GoPro cameras** available (GoPro2, GoPro3+, and Hero4) – True HD
- Recently, they are equipped with **external battery packs** for longer recording time (approx. **24 hours** with single charge, it used to be **1 hour**)
- Also, for **synchronization** purpose they are fitted with a **central start/stop feature**
Site Drones

- We have 2 drones
  - Both DJIs (Phantom Pro4 and Mavic Pro)
  - Ave. flight time 28 and 21 mins, respectively
  - 12 and 12.3 effective megapixels, respectively
  - 4K and HD video recording modes
  - They can take 360° pictures
  - Live video streaming via social media platforms
Wirecast System for Live Video Streaming

Wirecast Workflow

Plug in your cameras  
Capture your content  
Produce your show  
Stream it live

Audio/Video Sources  
Hardware  
Software: Wirecast  
Destinations

- 4 cameras can be hooked
- Has its own live streaming software
- Live production such as switching between multiple cameras while dynamically mixing with remote live guests, movies, images, audio etc.
- Streaming over popular social media platforms (YouTube, Facebook, Twitter etc.)
Control Center

- Houses host computer for shake table control
- Camera control system
- Data acquisition system
- Data and safety video streaming system
- FlexTest GT System
- Real-time hybrid testing system
  - Host and real-time target computers
Meeting/Conference Room
NHERI@UCSD Site IT Infrastructure

- 1-GB Campus Wide Area Network
  - Internet2 participant
- 802.11g Campus Wireless Network
  - WPA-2 Enterprise security
- Provide guest wireless account for visitors/researchers
- Site dedicated 1GB LAN
- Video/Data backup systems
Data/Video Backup System

- **On-site** data backup system (daily)
  - 16 TB

- **Off-site** data backup system (daily)
  - 16 TB

- Publish curated data/metadata in DesignSafe Data Depot
  - **Web interface** of DesignSafe
  - For large files use **Globus** bulk data transfer
The site has two different network systems:

• The general site network visible to the outside world
• The DAQ and Video intranet invisible to outside world
General Site IT Network (visible)

ESEC Facility Network Diagram

- SW Facility Internet
- NW Facility Internet
- Proxy Server
- Mobile Facility
- Fiber From 3560 Router
- FireWall
- Internet 2
- NHERI Hub2
  - Data Repository upload to designsafe-ci.org using Rsync
- NHERI Web Site
- 3560 Cisco Router and 3750 x28 Cisco Router
- UCSD Node B
- Kali/Snort for Pen testing and intrusion detection system
DAQ and VIDEO Intranet (invisible)

DAQ Subnet (10.0.0.100) Class C Intranet

UnderNeath Shake Table

DAQ 1 And 2
DAQ 5 And 6
DAQ 9 And 10

DAQ 3 And 4
DAQ 7 And 8

Data System
Seismic Table Controller

NHERI

Switch in Server Room

Control Room Downstairs

DAQ 11

DAQ 12

NHERI DATA Repository
The National Science Foundation sponsored Natural Hazards Engineering Research Infrastructure (NHERI) Experimental Facility at the University of California, San Diego will provide a large, high performance, outdoor shake table (LHPOST) to support research in structural and geotechnical earthquake engineering. Earthquakes have had considerable destructive effects on society in terms of human casualties, property and infrastructure damage, and economic losses. Building a multi-hazard, disaster-resilient, and sustainable environment requires the understanding and ability to predict more reliably the system-level response of buildings, critical facilities, lifelines, and other civil infrastructure systems to these extreme events. This facility will enable research, with extensively instrumented large- or full-scale structural, geotechnical, and soil-foundation-structural systems tested under extreme earthquake loads, to produce the experimental data essential to advancing predictive seismic performance tools. Research experiments performed using LHPOST will provide the size investigation that will transform the practice of earthquake engineering and educate graduate, undergraduate, and K-12 students, as well as the general public, about natural disasters and the national need to develop effective technologies and policies to prevent these natural hazard events from becoming societal disasters.

The LHPOST, with a steel platen that is 12.2 meters long by 7.8 meters wide, has performance characteristics that allow the accurate reproduction of near- and far-field earthquake ground motions. The facility will support seismic testing under near-real-world conditions, of large structural, nonstructural, geotechnical, and geotechnical systems, as well as soil-foundation-structural systems, up to a weight of 20 MN. Two large soil boxes can be used in conjunction with the shake table to investigate the seismic response of soil-foundation-structural systems. Software and hardware are available to support hybrid testing with substructures on the shake table. Systems tested at the facility can utilize extensive data acquisition and instrumentation capabilities, including a broad array of state-of-the-art sensors and high-definition video cameras, to support detailed monitoring through hundreds of data channels of the system response. The landmark system-level tests performed using this facility will provide fundamental knowledge and data to support the development, calibration, and validation of high-fidelity, physics-based computational models of structural, geotechnical, and soil-foundation-structural systems that will progressively shift the current reliance on physical testing to model-based simulation for the seismic design and performance assessment of civil infrastructure systems. These simulation tools will
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Social Media Presence (Youtube, Twitter, Facebook)
Questions?

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Dynamic Test Protocol
NHERI@UCSD vs. Nevada Reno Table

UCSD
1. Tune the bare table with TVC (bare table),
2. Train AIC to get an estimate of the inverse model of the plant (bare table),
3. Apply iteration with OLI at 1.0x (bare table),
4. Use the converged drive file from OLI iterations to perform the actual test (loaded table).

Nevada Reno
1. Tune the bare table with TVC (bare table),
2. Put the specimen on the table,
3. No tuning of 469D with the specimen on the table (loaded table),
4. Measure a model with AIC (loaded table),
5. In OLI, run 0.25x (that’s a single motion on the specimen),
6. In OLI, run 0.5x (that’s a single motion on the specimen),
7. In OLI, run 0.75x (that’s a single motion on the specimen),
8. … (up until the verge of collapse)