Assessment of Seismic Response of Nonlinear Structural System Using Deep-Learning

T. Kim¹, O. Kwon², and J. Song³

¹Graduate Student, Dept. of Civil and Environmental Engineering, Seoul National University
²Associate Professor, Dept. of Civil and Mineral Engineering, University of Toronto
³Professor, Dept. of Civil and Environmental Engineering, Seoul National University
Prediction of Seismic Responses of Nonlinear Systems
What is Deep Learning?

Artificial neural network (ANN)

- Deep learning (DL) is the application of the artificial neural network that utilizes multiple layers of nonlinear processing units to extract features of input data and find patterns of the problem to be solved.

Convolutional neural network (CNN)

- Designed to analysis or detect the features of data showing strong spatial correlation such as 2D images or speech signals
Structure of Proposed Neural Network Model
Dataset for training

- DB: Seismic source (EQ_Faults)
  - Type
  - Location
  - Slip rate

- DB: Earthquake event (EQ_Events)
  - Date
  - Magnitude
  - Epicenter, Hypo center
  - Etc.

- DB: Ground motion (EQ_Records)
  - Elastic response spectrum (RS)
  - RS based on absolute vector
  - File location
  - Etc.

- DB: Hysteretic model (SDOF_Models)
  - HM01: Elastic
  - HM02: Bilinear
  - HM03: Stiffness degradation
  - HMn:n:...

- DB: SDOF Parameters (SDOF_Realization)
  - Populated parameter values used for analyses and DB generation

- DB: SDOF Damping (SDOF_Damping)
  - Damping coefficient of SDOF system

- DB: Inelastic seismic demand of SDOF system (Seismic_Demands)
  - Max displacement
  - Max velocity
  - Etc.

1,499 Earthquake ground motions from NGA West

90 Linear
+90x30x10 Bilinear
+90x30x10 Bilin. w/ stiff. Degra.

81,080,910 analysis cases
Efficiency of the proposed method

- The elasto-perfectly plastic system with 200 GMs
- total dataset is $558,000 = 2,790 \times 200$.
- 8.03% of the dataset (44,842) shows nonlinearity during excitation

### Methods

<table>
<thead>
<tr>
<th>Methods</th>
<th>MSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-μ-T relationship</td>
<td>0.9857</td>
</tr>
<tr>
<td>Capacity spectrum method</td>
<td>0.3526</td>
</tr>
<tr>
<td>The coefficient method</td>
<td>0.6110</td>
</tr>
<tr>
<td>Deep neural network</td>
<td>0.0407</td>
</tr>
</tbody>
</table>

- Capacity spectrum method by FEMA 440 (2005)
- The coefficient method by ASCE 41-13 (2013)
Come see my Poster!

**Today Poster Session:**

- **Time:** 5:15 – 7:00 pm
- **Room:** Pasadena (Exhibit Hall)
- **Poster location:** Number 003