Pattern Recognition Approach to Assess the Residual Structural Capacity of Damaged Tall Buildings

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Tuesday, June 26 – Friday, June 29
Background and Motivation

• Framework motivated by need for models to support timely decisions about whether earthquake-damaged tall buildings are safe to reoccupy.

• Post-earthquake safety assessments are informed relationship between measured responses (or observed damage) and residual structural capacity.

• Tall building responses consist of a high dimensional feature space of global and local engineering demand parameters (EDPs), but it is impractical to obtain and use all EDPs (e.g. through inspection or remote sensing).
Framework Overview

- **Goal:** Develop a predictive model that takes in a subset of tall building responses (or observed damage) and provides a quantitative assessment of the residual structural capacity.
- **Criteria:** Peak story drift ratio (PSDR) corresponding to the collapse prevention (CP) limit state (0.045 per TBI and LATBSDC) is used as the performance criteria.
- **Measure:** Residual structural capacity quantified by $\kappa = \frac{\hat{S}_{a_{CP,DMG}}}{\hat{S}_{a_{CP,INT}}}$
- **Response patterns used as predictors:**
  - Peak story drift ratios (PSDR)
  - Residual story drift ratios (RSDR)
  - Frame beam rotations (FBR)
  - Concrete compressive strain (CCS)
  - Rebar tensile strain (RTS)
  - Coupling beam rotations (CBR)
NLRHA under Mainshocks

Dispersion-Based Filter

Median $\hat{S}_{\alpha_{CP,INT}}$ of Intact Structure

Median $\hat{S}_{\alpha_{CP,DMG}}$ of Damaged Structure

Support Vector Machine

Instrument/Inspection Data

Predictive Models

Predicted Residual Structural Capacity Index $\kappa_{CP}$

Path A

Path B

Path C

Path D
Description of Building Case
Apply Dispersion-Filtering to Features

- Raw dataset consists of 272 observations for the damaged tall building corresponding to 34 mainshock ground motions scaled to 8 different intensity levels.

- Each observation includes 84 PSDRs and RSDRs, 672 FBRs and FCRs, 252 CBRs and 420 WCSs and RTSs.

- Feature space dimension (2604) much larger than number of observations (272).
Apply Dispersion-Filtering to Features

- **Filtering** is done to avoid (1) multicollinearity and (2) very small response demands.
- **Dispersion** in structural responses increases with the demand level and extent of inelastic response.
LASSO-Based Feature Selection

LASSO uses penalized OLS Loss Function: 

$$J(w, \lambda) = \sum_{i=1}^{N} L(y_i, \hat{y}_i) + \lambda \|w\|_1$$
Profile of Feature Dispersions

Two sets of filtered features defined: selected and reserved
Profile of Feature Dispersions
Profile of Feature Dispersions
Support Vector Machines (SVM)
Performance of SVM Model Constructed using only Selected CBRs as Predictor
## Overall Performance of SVM Model

<table>
<thead>
<tr>
<th>EDP</th>
<th>RMSE</th>
<th>Number of Features</th>
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<tr>
<td></td>
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1 Reserved features not used for PSDR and RSDR
Example Application: Hypothetical Earthquake Sequence

- **Hypothetical sequence:** mainshock followed by four aftershocks occurring on 2\(^{nd}\), 4\(^{th}\), 12\(^{th}\) and 26\(^{th}\) day after the first event.
- **Key outcomes:** (1) reduction in structural capacity after each event and (2) time-dependent fragility curves.
Acknowledgements

National Science Foundation, CMMI Grant # 1538747.