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Fast nonlinear response history analysis

Juan C. Reyes, Associate Professor, Univ. de los Andes, Colombia
Erol Kalkan, Research Structural Engineer, USGS, USA
Armando Sierra, Master Student, Univ. de los Andes, Colombia
Excessive processing time

- PBE of Large structures
- Large number of ground motions
- Risk assessment (incremental dynamic analysis)
Objective

Develop a procedure for reducing the processing time of nonlinear response history analysis
**INTRODUCTION**

**OBJECTIVE**

**RESULTS**

**CONCLUSIONS**

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**Downsampling**

- **Leading weak signal**
- **Trim trailing signal**

**Downsampling**

<table>
<thead>
<tr>
<th>Larger time step</th>
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</thead>
</table>

- Depends on:
  - Structural behavior
  - Record characteristics
Phase 1: Estimating nonlinear roof displacement using an approximate procedure

- **Modal analysis**
- **Pushover analysis first 3 modes**
- **Idealizing pushover curves**
- **Run UMRHA (Chopra, 2007)**

\[ u_r \approx \sum_{n=1}^{N} \Gamma_n \phi_{rn} D_n(t) \]
Comparison between exact and approximated roof displacement.

**Exact**

\[ u_{rx}(t), \text{ in} \]
\[ u_{ry}(t), \text{ in} \]

**PERFORM 3D**
**UMRHA**
Phase 2: Trimming the leading weak signal

\[ u_r(t) \]
Phase 3: Trimming the trailing weak signal

\[ \ddot{u}_g(t) \]

\[ \dot{u}_r(t) \]

Trim trailing signal

\[ f_j \cdot \max(|u_r(t)|) \]

\[ \max(|u_r(t)|) \]
Phase 4: Downsampling (adapted from Zhong and Zareian, 2014)

FFT of approx. roof displacement → New time step equal to $\pi/\omega_{cut}$ every 0.005 s → Resample the record

Low pass filter after $\omega_{cut}$

A Matlab toolkit is available
Parametric study using idealized structures

(a) Three-dimensional idealized structure

(b) Story shear vs. story drift

\[ 2V_s/R \]

\[ V_s/R \]

\[ \Delta_y \]

\[ 3.5\Delta_y \]

\[ i^{th} \text{ story element} \]
Percentage of error in story drifts for values of $f_i$, $f_m$ and $f_f$
Percentage of reduction in the number of time steps

<table>
<thead>
<tr>
<th>Linear</th>
<th>$R = 3$</th>
<th>$R = 5$</th>
<th>$R = 7$</th>
<th>Reduction, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_i, %$</td>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
<td><img src="image3" alt="Graph" /></td>
<td><img src="image4" alt="Graph" /></td>
</tr>
<tr>
<td>$f_m, %$</td>
<td><img src="image5" alt="Graph" /></td>
<td><img src="image6" alt="Graph" /></td>
<td><img src="image7" alt="Graph" /></td>
<td><img src="image8" alt="Graph" /></td>
</tr>
<tr>
<td>$f_f, %$</td>
<td><img src="image9" alt="Graph" /></td>
<td><img src="image10" alt="Graph" /></td>
<td><img src="image11" alt="Graph" /></td>
<td><img src="image12" alt="Graph" /></td>
</tr>
</tbody>
</table>
Study cases

\[ f_i = 10\% \quad f_m = 10\% \quad f_f = 20\% \]

- **R05**: Corner column
- **R09**: Girder x-dir
- **R15**: Girder y-dir

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5 stories

9 stories

15 stories
Conclusions

- The average reduction in time steps are 60%, 70% and 76% for 5, 9 and 15 story buildings, respectively.
- The proposed procedure decreases the processing time of nonlinear response history analysis without compromising accuracy.