
RIC 2024 Hybrid
U.S. Nuclear Regulatory Commission
36th Annual Regulatory Information Conference
ADAPTING TO A
CHANGING LANDSCAPE
MARCH 12-14, 2024
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Digital Exhibit 28

Demonstration of Response Spectrum Matching Using the Greedy Wavelet Method (GWM)

(1) GWM is fast, stable, and easy to use in developing seismic design acceleration time histories from design response spectra (RS)

(2) GWM helps ensure the sufficiency of the power spectral density (PSD) functions of the developed acceleration time histories

Presented by
Structural, Geotechnical, and Seismic Engineering Branch
Division of Engineering, Office of Nuclear Regulatory Research, U.S. NRC

GWM's Origin and Future—From Research to Application

- The NRC staff developed GWM to meet a research need for hundreds of spectrally matched seismic acceleration time histories
  - Those time histories were used to estimate the uncertainties in in-structure RS
- GWM's computational advantages can be leveraged for seismic analysis and design of advanced nuclear reactors
  - Many advanced reactor designs are expected to use seismic time history analyses to simulate complex interactions of innovative systems, such as seismic isolation and water pools

RspMatch09 → GWM

Representative Wavelet-Based, Time Domain RS-Matching Methods

1978 Kaul
Spectrum-consistent time-history generation, *J. Eng. Mech.* Div. 104, no. 4, 781–788.

1988 Lilhanand and Tseng
Development and application of realistic earthquake time histories compatible with multiple-damping design spectra, *Proc. of the Ninth WCEE*, Tokyo, Japan, 2–9 August 1988.

1992 Abrahamson
Non-stationary spectral matching, *Seismol. Res. Lett.* 63, 30.

2006 Hancock, et al. (incl. Abrahamson)
An improved method of matching response spectra of recorded earthquake ground motion using wavelets, *J. Earthq. Eng.* 10, no. s1, 67–89.

2010 (RspMatch09) Al Atik and Abrahamson
An improved method for nonstationary spectral matching, *Earthq. Spectra*, 26, no. 3, 601–617.

2023 Nie, Graizer, and Seber
A greedy algorithm for wavelet-based time domain response spectrum matching, *Nuclear Engineering and Design*, **410**(1123843); https://doi.org/10.1016/j.nucengdes.2023.112384

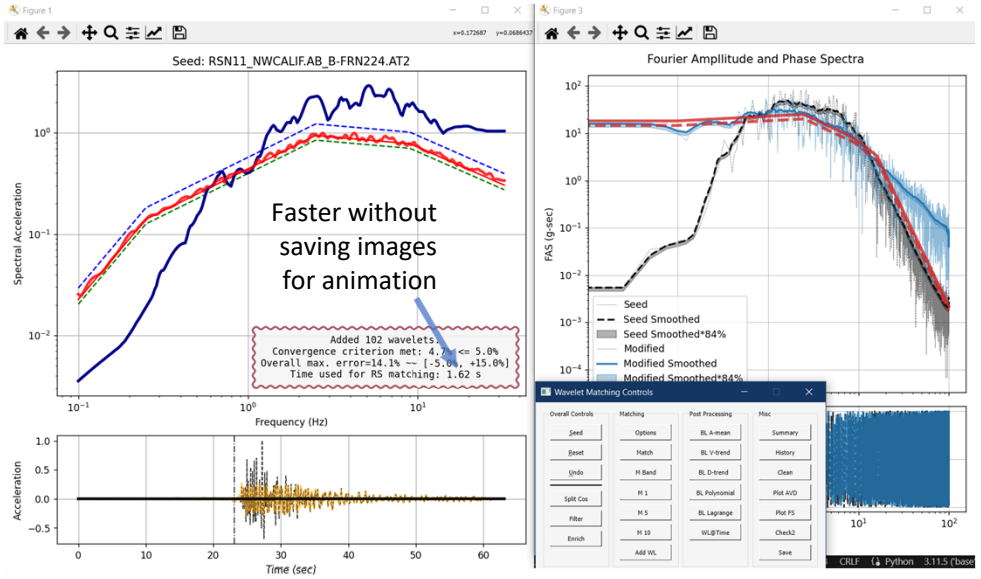
- **GWM** does not need to solve an optimization problem in each iteration
- **GWM** uses significantly fewer wavelets to achieve RS convergence (saving 99.5% for the RspMatch09 example)
- **GWM** helps achieve the sufficiency of the PSD functions of the developed acceleration time histories
- **GWM** provides interactive and powerful baseline correction tools through its graphical user interface

Text Input & Output vs Graphical User Interface

```
15                          \maximu
0.05                        \tolera
1.0                         \conver
7                           \model
1.25 0.25 1.0 4.0           \alpha
0  0.                       \scale
1                           \interp
1.0e-04                     \minimu
30                          \group
35.                         \max fr
0.0 0.0 4                   \fBand_
0                           \Mod PC
0  0.0                      \randor
0.1  35.                \freqMatch
0             \baseline cor flag
1.0               \scale factor
Input Files\cms_T0.2_horiz.tgt
Output Files\Run3.acc
Output Files\Run4.acc
Output Files\Run4.rsp
```

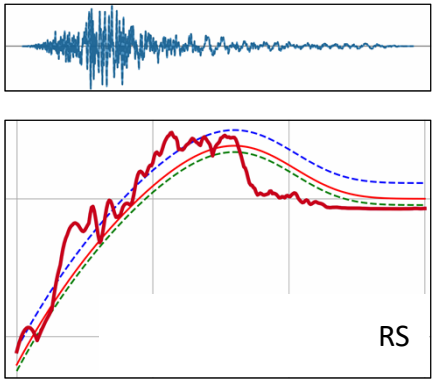
```
Solution did not converge in maxi
Maximum misfit =   13.09 percent
Input Parameter File:Input Files\

Run Parameters:
Input time history:  Output Files
Output time history: Output Files
Target spectrum:     Input Files\
Maximum number of iterations =
Convergence tolerance =    0.0500
Convergence Damping factor =    1
Adjustment time history model =
Adjustment TH tapers (a1,a2,f1,f2
Interpolate TH Flag =    1
Scale TH Flag =    0
No Scaling Applied
minimum eigenvalue =  0.1000E-03
Group Size =   30
Max Freq (Hz) =  219.9115
Filter Parameters:
F1, F2, Npole:     0.00    0.00
PGA Not Modified
```

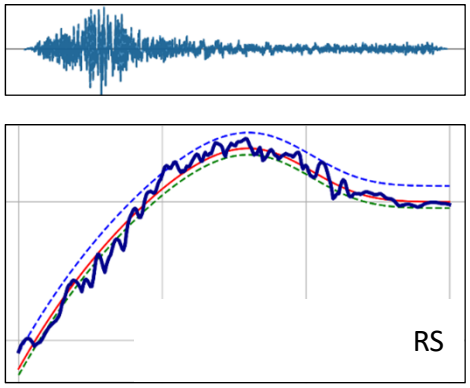


One Way to Achieve Both Power Sufficiency and RS Convergence

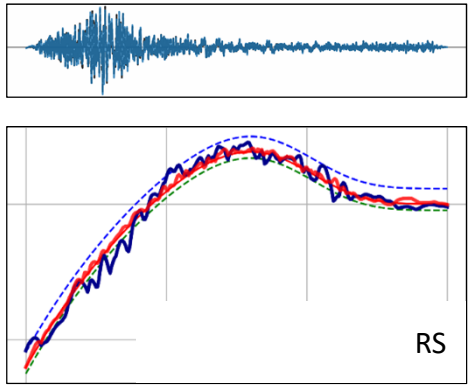
1. Select an initial seed record



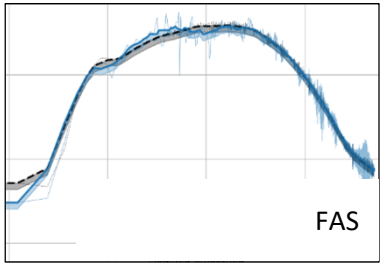
2. Use target PSD to replace Fourier amplitudes



3. Use GWM for RS matching



Smooth & broad Fourier amplitude spectra (FAS)



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Thank you for checking out GWM!

Presented by

JS Nie, Jose Pires, Laurel Bauer, Ryan Payne,
Thomas Weaver, Vladimir Graizer, and Weijun Wang

Structural, Geotechnical, and Seismic Engineering Branch
Division of Engineering, Office of Nuclear Regulatory Research, U.S. NRC

DE28 Coordinator Email: *Jinsuo.nie@nrc.gov*.