Intuitive Error Correction Algorithm for Pseudodynamic Testing

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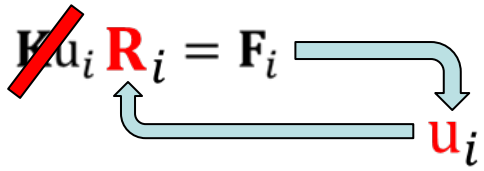
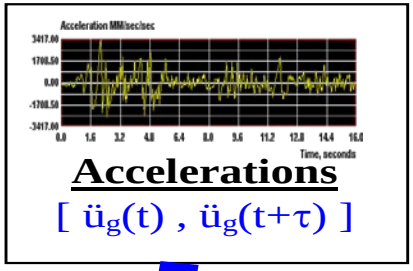
Background

- The underlying concept is to solve the equation of motion
- According to structural dynamic theory:
  - $\mathbf{M}\mathbf{a}_i + \mathbf{C}\mathbf{v}_i + \mathbf{R}_i = \mathbf{F}_i$



- Where M : mass matrix
  C : viscous damping matrix
  R : restoring force vector
  F : external excitation
  subscript i denotes at time-step i



Accelerations

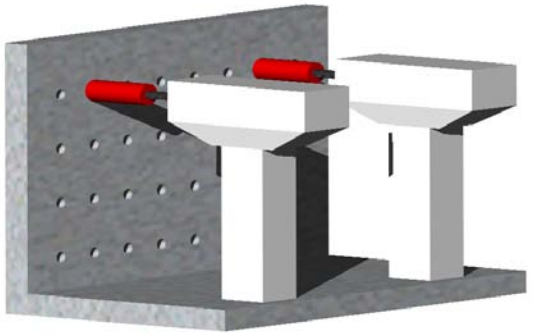
$[\ \ddot{u}_g(t)\ ,\ \ddot{u}_g(t+\tau)\ ]$

1) Input asynchronous ground accelerations & calculate displacements

2) Impose displacements from FE model

Computer FE model

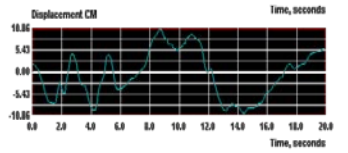
$$[M]\ r\ [\ddot{u}_g] = [M]\ [\ddot{u}] + [C]\ [\dot{u}] + F([u])$$



Physical Test Specimen

- Load cells → F([u])

3) Measure restoring force and recalculate displacements



Time history result

$[u\ ,\ \dot{u}\ ,\ \ddot{u}\ ]$

Comparison to Shake-table Test

Advantages

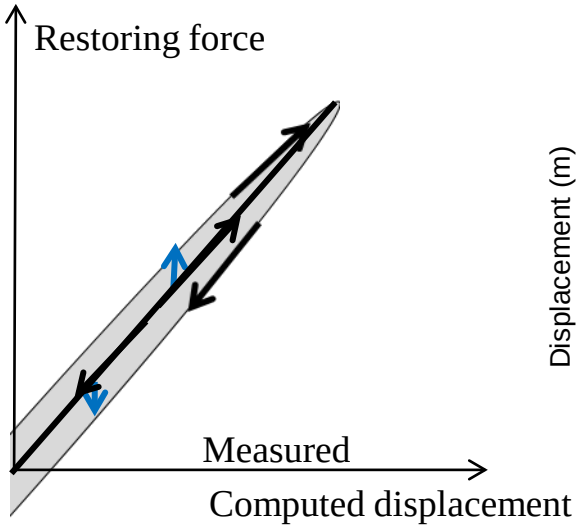
- Load can be applied slowly
- Tests on large / full scale structures

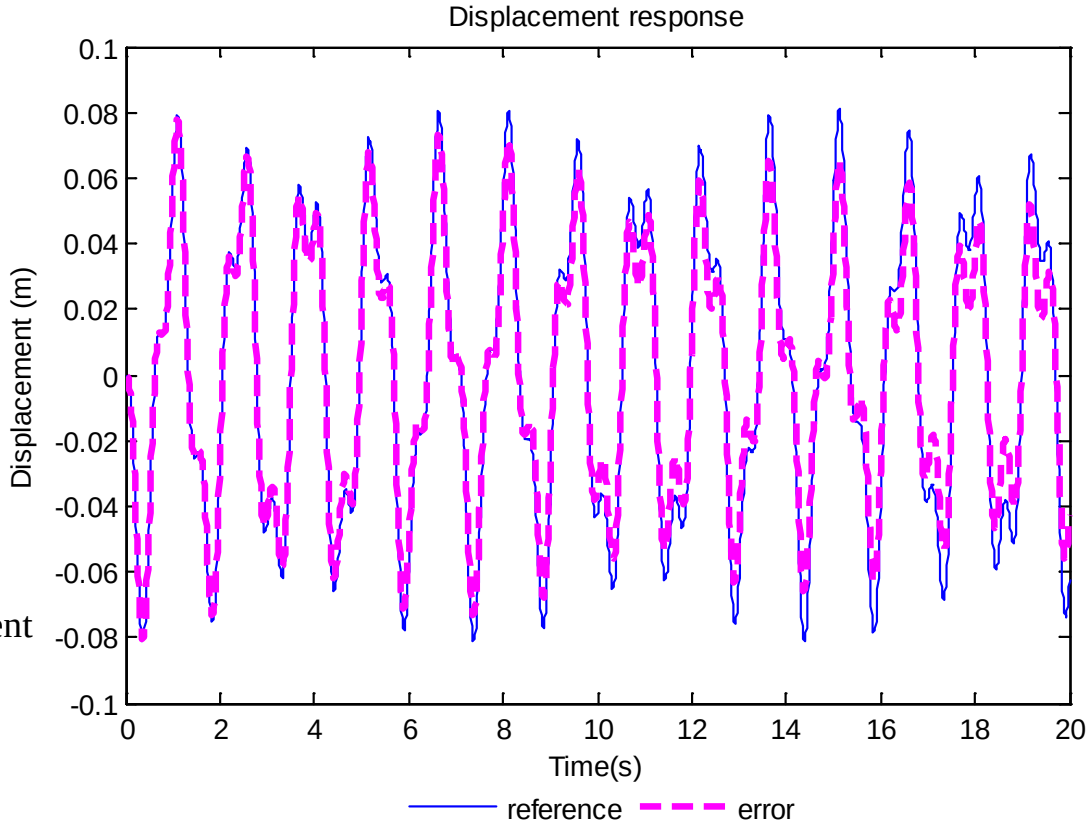
Disadvantages

- Strain-rate effect is not represented
- Prone to errors:
  - Random error
  - Systematic error
    - Displacement control error

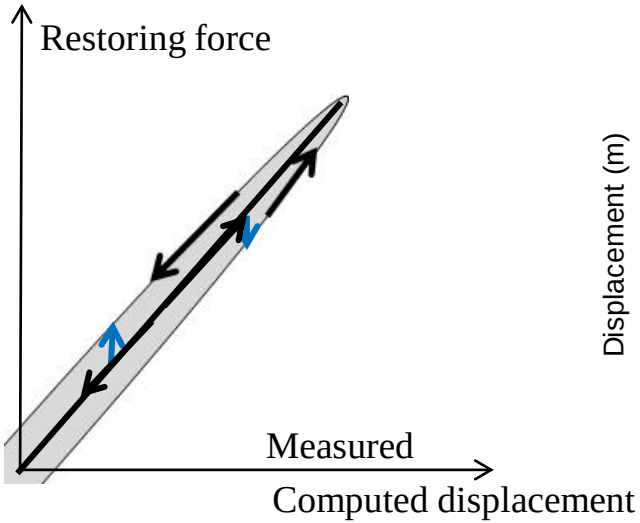
Displacement Control Error

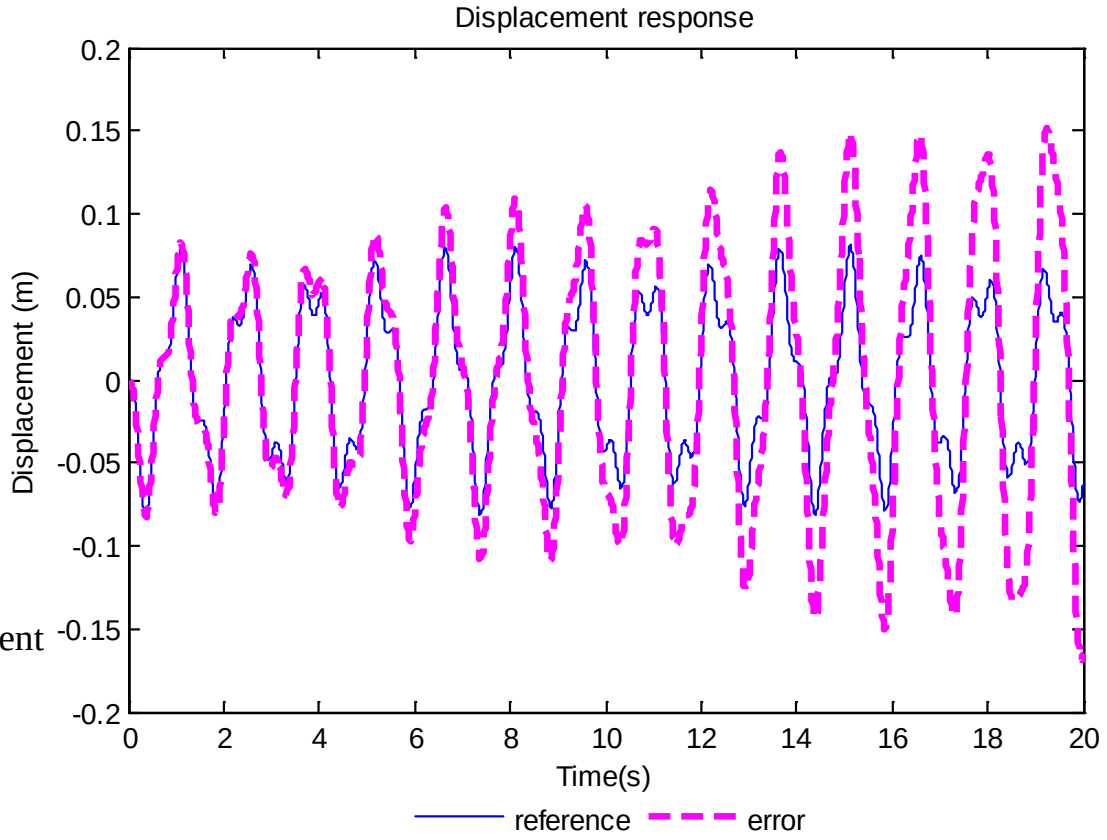
- Systematic overshooting





- Systematic Undershooting/Lag





Proposed actuator delay compensation

- HSEM (Mosqueda et al. 2007): monitoring the accumulation of energy error against a specified threshold
- New intuitive algorithm: convert energy error into viscous damping coefficient
- Specimen energy:

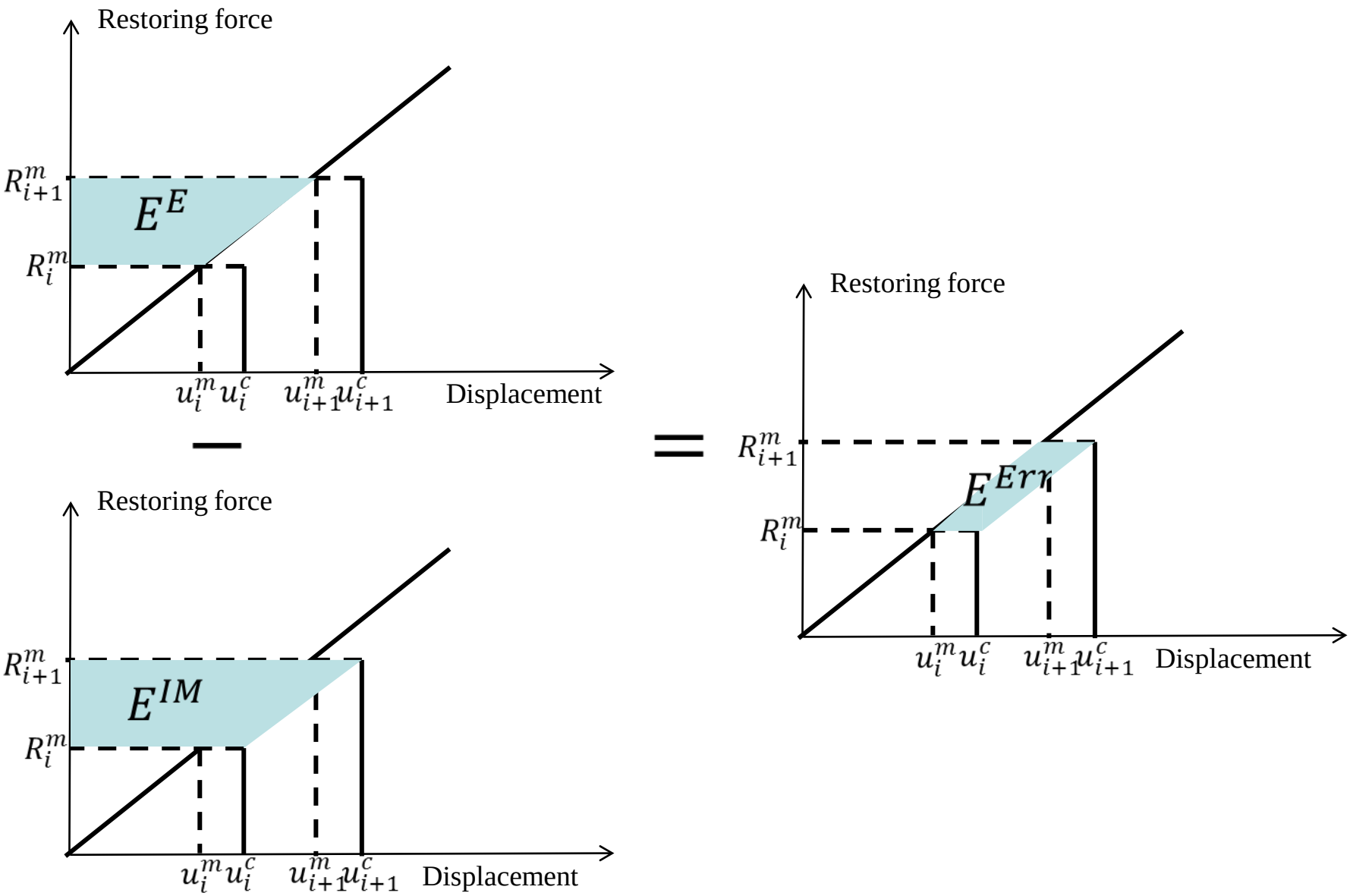
$$E_{i+1}^{E} = \frac{1}{2}(u_i^m + u_{i+1}^m)(r_{i+1}^m - r_i^m)$$

- Integration energy:

$$E_{i+1}^{IM} = \frac{1}{2}(u_i^c + u_{i+1}^c)(r_{i+1}^m - r_i^m)$$

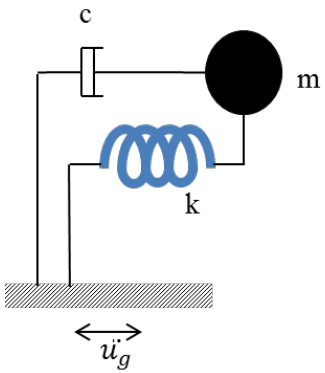
- Energy error:

$$E_{i+1}^{Error} = E_{i+1}^{E} - E_{i+1}^{IM}$$


Restoring force
R_{i+1}^m
E^E
R_i^m
u_i^m u_i^c
u_{i+1}^m u_{i+1}^c
Displacement
—
Restoring force
R_{i+1}^m
E^{IM}
R_i^m
u_i^m u_i^c
u_{i+1}^m u_{i+1}^c
Displacement
=
Restoring force
R_{i+1}^m
E^{Err}
R_i^m
u_i^m u_i^c
u_{i+1}^m u_{i+1}^c
Displacement

Numerical Simulation

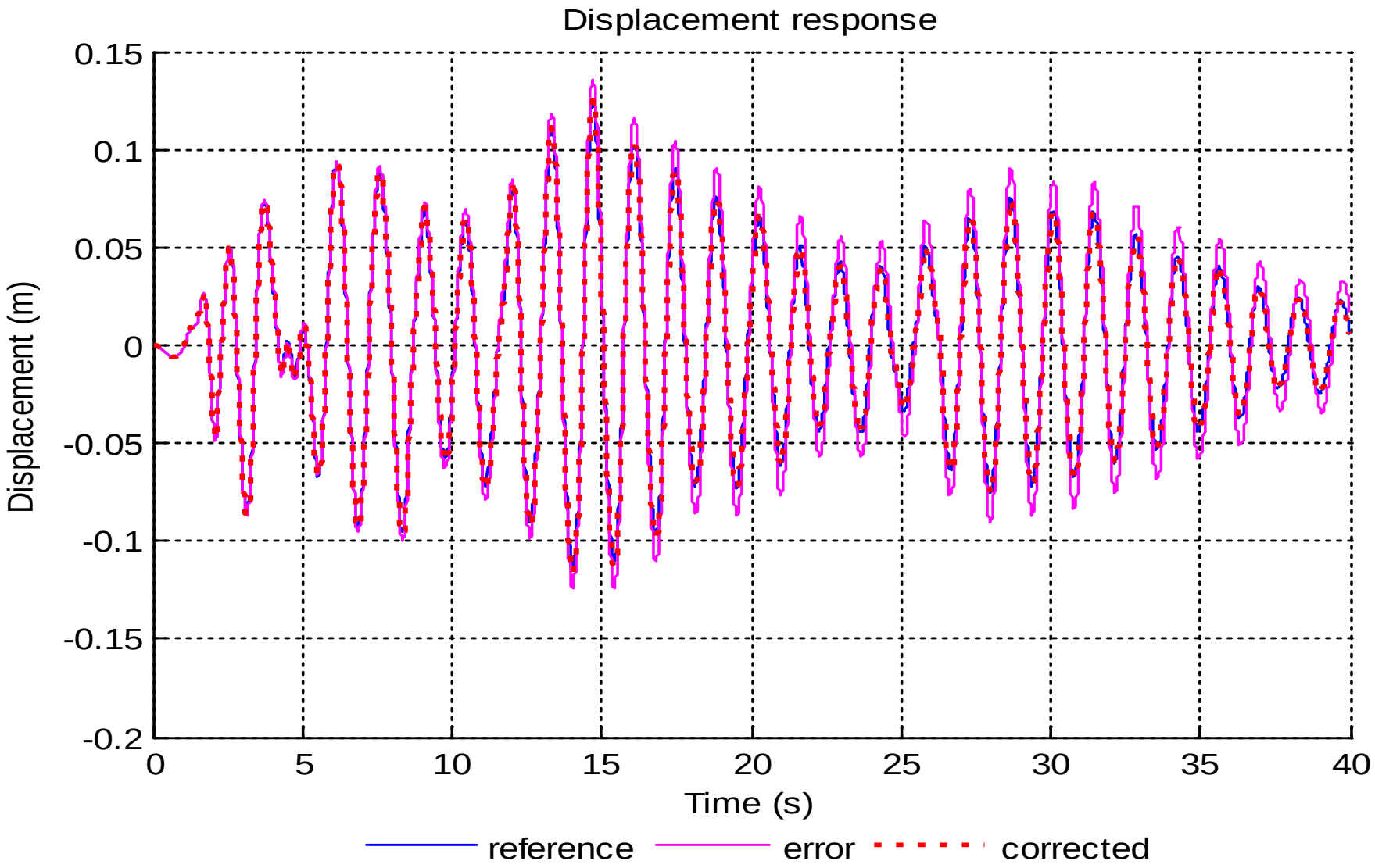
- Linear-elastic SDOF structure



Structural properties	
m (KNs²/m)	*50*
k (KN/m)	*1000*
ζ (critical damping ratio)	*0.02*
T (seconds)	*1.4*

- Excitation properties
  - 1940 El Centro earthquake
  - Variable actuator delay

Simulation Result



Conclusion & Immediate Future Work

- The validity of the method has been confirmed through numerical simulation
- Easy to implement
- Confirmation of validity in MDOF system
- Application in slow pseudodynamic test using optimally and non optimally tuned actuator

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Thank You!

- Questions?