Hybrid Simulation: Simulation Errors

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Introduction

ERROR SOURCES

• Errors due to Structural Modeling
• Errors due to Numerical Methods
• Experimental Errors
Errors due to Structural Modeling

- Structural Idealization
  - Discrete parameter system
  - Lumped mass vs Consistent Mass Matrices

- Modeling Damping
  - Viscous Damping is represented analytically
  - Spurious moments introduced when stiffness proportional damping is used

Errors due to Numerical Methods

- Explicit methods are conditionally unstable, therefore require shorter time steps
- Unconditionally stable methods may require short time steps for accuracy depending on the periods of the considered system
- Higher modes are more susceptible to error propagation than the lower modes. Therefore, numerical damping is desirable for suppressing higher mode errors
- However, numerical damping may lead to errors if it reduces lower mode participation
- Use of initial stiffness matrix instead of tangential stiffness matrix for experimental substructures may lead to errors
Experimental Errors – Random Errors

- Random errors
- Systematic errors

• Random errors have no distinguishable pattern and generally no specific physical effects can be anticipated
  - Random electrical noise in wires and electronic systems
  - Random rounding-off or truncation in the A/D conversion of electrical signals
  - Random noise in the measured forces can be problematic. This noise in can excite spurious response in high frequency modes. Possible solutions
    - Numerical damping
    - Filtering
    - Momentum equation of motion

Experimental Errors – Systematic Errors

- Systematic errors may lead to error propagation and numerical instability
  - Servo-hydraulic closed control loop
  - Measurement errors
  - Hybrid simulation technique (ramp and hold, continuous, real-time)

- Control loop errors
  - Actuator dynamics
    - Servo-valve
    - Hydraulic power-supply
  - Control-loop dynamics
    - Inherent lag in the displacement response
    - PID gains
Integration: Command displacement versus measured force
True behavior: Measured displacement versus measured force

- Integration methods which introduce numerical damping to suppress the excitation of higher modes can be used to overcome the effects of these errors
- Adaptive minimal control synthesis (MCS) algorithm which provides adaptive gain settings as the test specimen properties change can be used instead of PID control algorithm
Experimental Errors – Systematic Errors

- Measurement errors - Errors in the loadcells and displacement transducers of the actuators
  - Calibration
  - Friction or slop in the attachments
  - A/D and D/A conversion

Digital controllers and digital transducers for improved accuracy

Experimental Errors – Systematic Errors

- Errors due to the hybrid simulation technique

Ramp and Hold Method

- Force relaxation during hold phase
- The discontinuity in velocity at the transition from the ramp to the hold phase can result in overshooting of the target displacements for poorly tuned gain settings (Thewalt and Mahin 1987)
Continuous Testing (Predictor-Corrector Algorithms)

!!! Predictor-Corrector Algorithms for continuous testing should not be confused with the predictor-corrector integration methods.

Continuous Testing (Three Loop Architecture (Schellenberg et al., 2009))
Experimental Errors – Systematic Errors

- Errors due to the hybrid simulation technique

  Real-time testing

  - There is an inherent lag in the displacement response of servo-hydraulic actuator versus the command displacement. This actuator delay may become critical for real-time testing.

  - To compensate for this lag, Horiuchi et al. (1999) measured the time lag of the actuator response and predicted the command of the actuator by advancing the current time in the algorithm by the delay time.

  - Elkhoraibi and Mosalam (2007) used a method in which a relation between the actuator velocity and displacement error is obtained and the command displacement is adjusted by adding the predicted error to the original command signal

References


Thank you

Questions ?