Nonlinear AeroServoElastic Reduced Order Model for Active Structural Control

Topic: A2.04 Aeroelasticity, PI: Yi Wang, Project No. NNX12CD51P

SBIR STTR

Identification and Significance of Innovation

- Aeroelastic and aeroservoelastic models are extensively used in analysis and design of NASA aircrafts and aerospace vehicles
- Existing full-scale CFD simulation and aeroelastic reduced order model (ROM) techniques are not particularly useful for aeroservoelastic analysis and flight control due to high computational costs and slow speeds
- There is a critical need to develop innovative tools to generate integrated, ultra-fast (real-time), nonlinear, parameter-varying ROMs for efficient ASE studies at reduced time and cost
- Proposed solution leverages technological advancements in model order reduction techniques, aeroservoelasticity, and software development

Technical Objectives & Work Plan

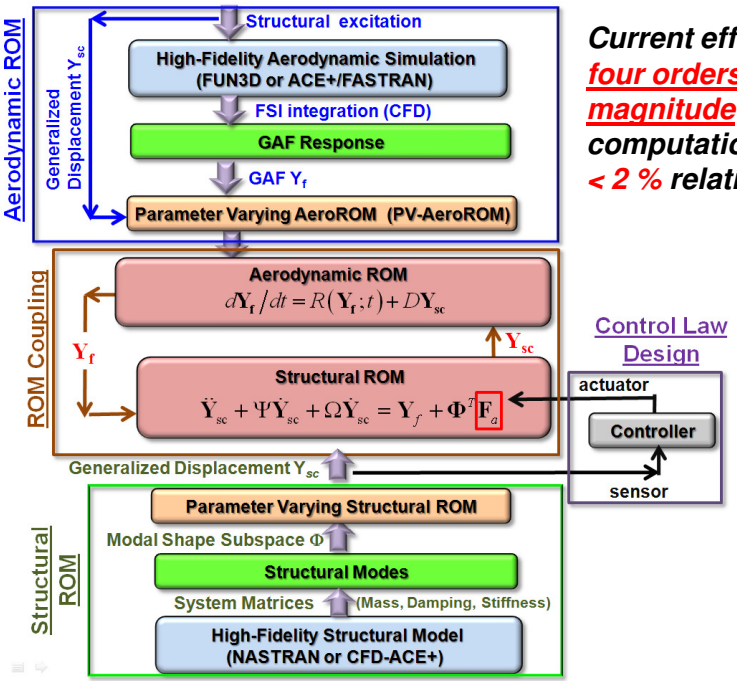
Develop reliable reduced order modeling algorithms and software to automatically generate ASE ROM for active structural control. Specific Phase 1 technical objectives were:

- Develop a nonlinear aerodynamic ROM using system identification methods
- Develop a structural ROM based on modal shape projection method
- Design a software framework enabling the coupled aerodynamic, structural, and electromechanical simulation, data exchange, and ROM verification
- Demonstrate the software by performing ASE case studies of NASA interest

Phase I Accomplishments (TRL3)

All Phase I goals were successfully accomplished and exceeded, including:

- Six multiple-input, multiple-output system identification engines were successfully developed to generate accurate aerodynamic ROMs
- Structural ROM engines for the smart material-based structural control and flap control were successfully developed for ASE analysis.
- A modular simulation architecture was established to interface high-fidelity CFD tool, integrate the key components, and streamline the entire process.
- Software validation and demonstration by coupling the ROMs and controller for integrated simulation: **>10,000× speedup and < 2% relative error**.
  - Nonlinear ROM performs saliently at the nonlinear transonic regime: **1.25 % relative error and >17,000× speed up**.
  - ASE ROMs demonstrated flutter suppression with markedly enhanced flight performance by using surface control (flap)



Current effort enables four orders-of-magnitude reduction in computational time with < 2 % relative error

NASA Applications

- Enable rapid and computationally affordable analysis for optimal aerodynamic and structural design of aircrafts and aerospace vehicles
- Develop advanced, reliable ASE control strategies (such as controlled maneuver, and AE instability control, e.g., buffet, flutter, and buzz)
- Properly arrange test procedures for rational use of instruments and facilities

Non-NASA Applications

- Broad applications in aerospace, aircraft, and watercraft engineering sectors involving fluid-structure-control interaction (Air Force, Missile Defense, Navy, business aircraft, automobile, and power industry etc.)

Firm Contacts

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