An Adaptive Mesh Refinement (AMR) Strategy For Static & Dynamic Overset Unstructured Meshes

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Overview

Why use Mesh Adaptation?
- No need to tailor mesh to flow phenomena
- Capture wake physics without coupling with a hybrid code
- Anisotropic Adaptation
- Can accurately capture tip vortices

Refinement capability within FUN3D
- Feature and adjoint-based anisotropic AMR for unstructured tetrahedral meshes
- Previously used in non-overset cases with no indicator to capture vortices and wake structures

Previous AMR efforts in Rotorcraft
- Overset methods
- Background mesh is adapted
- Hover conditions – Canonne et al.
- Structured near-body – Duque et al.
- Non-overlaid and sliding mesh approaches
- Adaptation in body-fixed frame

Overset Adaptation Technique

What is unique about this?
- Overset method (SUGGAR++) using single unstructured RANS solver (FUN3D)
- Anisotropic AMR with vorticity-based indicator
- Adaptation performed in intertial reference frame

Parallelized Adaptation Mechanisms
- Node insertion and movement
- Edge swap and collapse
- Iteratively satisfies anisotropic metric M

Overset AMR Strategy:
- AMR restricted only to background mesh
- Performed at intervals to capture unsteady wake’s evolution

Adaptation Indicator
\[ \rho \times (\text{edge length})^{1.0} \]

Frozen Nodes of Overset AMR:
- All near-body mesh nodes
- Holes points of background mesh

Rotor-Fuselage Configuration: ROBIN

Generic rotor-fuselage (NASA)
- Rotorcraft CFD validation case
- Unsteady pressure data correlation desired
- CFD does not model complex rotor hub


Unadapted (left) and Adapted (right) Mesh Contours at r/R = 0.56 (retreating side)

Unadapted (left) and Adapted (right) Iso-Vorticity Surfaces

BVI effects
- Complex to vortex rollup
- Vortex sheet development

Unsteady pressure correlation
- Adaptation damps out high order oscillations
- Better magnitude agreement at empennage locations – \( x_f = 1.18 & 1.56 \)
- Smooth pressure prediction at \( x_f = 0.55 \) due to accurate root vortices

Applications & Ongoing Research

Sling Loads
- Aerodynamic effects on dynamic modes
- Drag prediction

Source: (left) US Army FM 4-20.198, Feb. 2009
- (right) B. Koukol, Georgia Tech

Wind Turbines
- Tower and nacelle contributions to wake
- Full configuration interactions

- (right) C.E. Lynch, Georgia Tech

Hub Drag
- Rotor-hub interaction
- Component drag buildup
- Assembly interactions

Current & Future Work

Capture longer wake-ages similar to VTM (left)


- Overset AMR process currently quite complex
- Integration of adaptation and overset capability
- Effective communication between libraries
- Increased efficiency and robustness
- Develop a time-dependent metric-based approach
- Better accuracy in capturing unsteady features
- Less sensitive to adaptation frequency

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