Computational Aircraft Prototype Syntheses

Training Session 11

Data Transfer: Loosely-Coupled Aeroelasticity

ESP v1.18

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Overview

- Loosely coupled analysis
- `capsBound` object and the `capsBound` attribute
  - `capsVertexSet` objects
  - `capsDataSet` objects
- Loosely coupled one-way modal aeroelastic analysis
- Loosely coupled two-way iterative aeroelastic analysis
- Enhanced CAPS and Final Thoughts

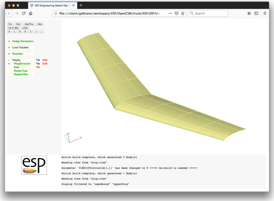
Loosely coupled Analysis Overview

- Couple two independent analysis tools
- Aeroelastic analysis
  - CFD to compute pressures
  - FEM to compute displacements
- Typically disparate tools
  - Mesh resolution
  - Data representation (cell vs. node center)
- CAPS data transfer reconciles differences
- Examples:
  - One-way coupling: Astros Modal → Fun3D
  - Two-way coupling: Astros Static ↔ SU2

capsBound object and attribute

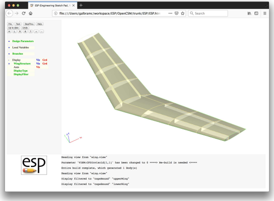
- `capsBound` is a logical grouping of BRep Objects
  - Represent the same entity, e.g. “outer surface of the wing”
- Bound is used by CAPS framework to facilitate data transfer
  - Defined by the `capsBound` attribute
- Same `capsBound` attribute applied to “coincident” bodies defines connection

ESP/wing3.csm Structures `capsBound`



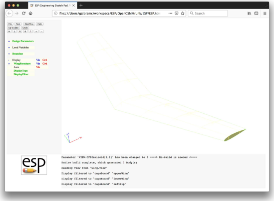
```
Entire build complete, which generated 3 Body(s)
Reading view from "wing.view"
Parameter 'VIEW:CFDInviscid[1,1]' has been changed to 0 =====> Re-build is needed <=====
Entire build complete, which generated 1 Body(s)
Reading view from "wing.view"
Display filtered to "capsBound" "upperWing"
```

`ATTRIBUTE capsBound $upperWing`



```
Reading view from "wing.view"
Parameter 'VIEW:CFDInviscid[1,1]' has been changed to 0 =====> Re-build is needed <=====
Entire build complete, which generated 1 Body(s)
Reading view from "wing.view"
Display filtered to "capsBound" "upperWing"
Display filtered to "capsBound" "lowerWing"
```

`ATTRIBUTE capsBound $lowerWing`



```
Parameter 'VIEW:CFDInviscid[1,1]' has been changed to 0 =====> Re-build is needed <=====
Entire build complete, which generated 1 Body(s)
Reading view from "wing.view"
Display filtered to "capsBound" "upperWing"
Display filtered to "capsBound" "lowerWing"
Display filtered to "capsBound" "leftTip"
```

`ATTRIBUTE capsBound $leftTip`

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- `capsBound` is a logical grouping of BRep Objects
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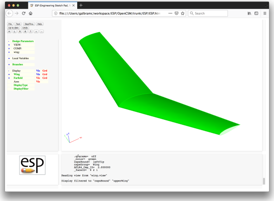
ESP/wing3.csm CFD Inviscid `capsBound`

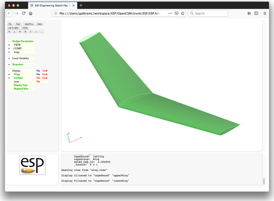


```
        .qParams=  off
        _color=  green
        capsBound=  leftTip
        capsGroup=  Wing
        AFLR4_Cmp_ID=  2.000000
        _faceID=  9 2 1

Reading view from "wing.view"

Display filtered to "capsBound" "upperWing"
```

`ATTRIBUTE capsBound $upperWing`



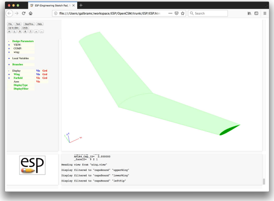
```
        capsBound=  leftTip
        capsGroup=  Wing
        AFLR4_Cmp_ID=  2.000000
        _faceID=  9 2 1

Reading view from "wing.view"

Display filtered to "capsBound" "upperWing"

Display filtered to "capsBound" "lowerWing"
```

`ATTRIBUTE capsBound $lowerWing`



```
        AFLR4_Cmp_ID=  2.000000
        _faceID=  9 2 1

Reading view from "wing.view"

Display filtered to "capsBound" "upperWing"

Display filtered to "capsBound" "lowerWing"

Display filtered to "capsBound" "leftTip"
```

`ATTRIBUTE capsBound $leftTip`

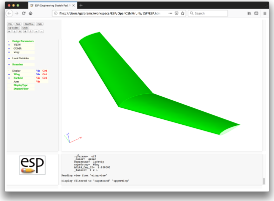
capsVertexSet object

- capsVertexSet is a discrete capsBound

capsBound

capsVertexSet

Aerodynamic



```
        .qParams=  off
        _color=  green
        capsBound=  leftTip
        capsGroup=  Wing
        AFLR4_Cmp_ID=  2.000000
        _faceID=  3 2 1
Reading view from "wing.view"
Display filtered to "capsBound" "upperWing"
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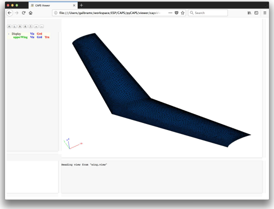
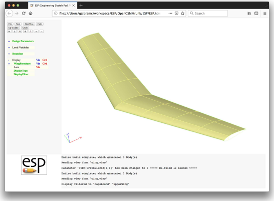


```
Reading view from "wing.view"
```

Structures



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Reading view from "wing.view"
Display filtered to "capsBound" "upperWing"
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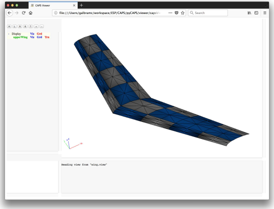

```
Reading view from "wing.view"
```

capsVertexSet object

- capsVertexSet is a discrete capsBound

- If capsBound Faces have same underlying surface, then the native UVs are used to match the points between capsVertexSets
- If not the triangulations are reparameterized with a single UV representation
- If barycentric coordinates are found for each vertex in a capsVertexSet to the other(s). This allows for straight interpolation using the solver's spatial discretization scheme (as provided in the AIM)

capsDataSet object

capsDataSet

- Discrete data associated with a capsVertexSet
  - Pressure
  - Temperature
  - Displacements
- Flexible data structure
  - Node centered data
  - Cell centered data
  - Higher-order nodal basis functions

Data Transfer: Interpolate vs. Conservative

- Data transferred between different `capsVertexSet`
  - Pressure from aero to structures `capsVertexSet`
  - Displacements from structures to aero `capsVertexSet`
- Transfer via interpolation:
  - Interpolation, does not insure integrated values match between `capsVertexSets` – important for a convergent inner loop
- Conservative transfer:
  - Conservative data transfers ensure integrated quantities match by slightly adjusting (weighting) the interpolation.

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Example of Modal Data Transfer

- Compute EigenVectors with Astros
- Transfer EigenVectors to Fun3D for aeroelastic calculation

session11/aeroelastic_Modal_Fun3D_Astros.py

- Load aflr4AIM
- Load aflr3AIM
- Load fun3dAIM
- Load egadsTessAIM
- Load astrosAIM

- Create `capsBound` data transfers
- Generate meshes
- Fill `capsVertexSet`
- Execute ASTROS
- Transfer EigenVectors from ASTROS to Fun3D
- Execute Fun3D

Modal Data Transfer: Create Transfer

- variableName: Variable names
- aimSrc: AIM names to transfer data from (source)
- aimDest: AIM names receiving data (destination)
- transferMethod: Interpolate or Conserve
- capsBound: Name of the `capsBound` attribute on the bodies
- Builds dictionary myProblem.dataBound[bound]

session11/aeroelastic_Modal_Fun3D_Astros.py

```
# Create an array of EigenVector names
numEigenVector = 3
eigenVector = []
for i in range(numEigenVector):
    eigenVector.append("EigenVector_" + str(i+1))

# Create the capsBounds for data transfer
transfers = ["upperWing", "lowerWing", "leftTip", "riteTip"]
for bound in transfers:
    myProblem.createDataTransfer(variableName   = eigenVector,
                                 aimSrc         = [astros.aimName]*numEigenVector,
                                 aimDest        = [fun3d.aimName]*numEigenVector,
                                 transferMethod = ["Conserve"]*numEigenVector,
                                 capsBound      = bound)
```

Modal Data Transfer: Generate Mesh

- Generate meshes with pre/post Analysis
- Populate vertex sets

session11/aeroelastic_Modal_Fun3D_Astros.py

```
# Run AIM pre/post-analysis to generate the meshes
for aim in [aflr4.aimName, aflr3.aimName, tess.aimName]:
    myProblem.analysis[aim].preAnalysis()
    myProblem.analysis[aim].postAnalysis()

#--------------------------------------------------------------------------------#

# Populate vertex sets in the bounds after the mesh generation is copleted
for bound in transfers:
    myProblem.dataBound[bound].fillVertexSets()
```

Modal Data Transfer: Execution

- Execute Astros
- Transfer each EigenVector for each `capsBound`

session11/aeroelastic_Modal_Fun3D_Astros.py

```python
#Execute the dataTransfer
print ("\nExecuting dataTransfer ......")
for bound in transfers:
    for eigenName in eigenVector:
        myProblem.dataBound[bound].executeTransfer(eigenName)
```

- Execute Fun3D

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Example of Iterative Data Transfer

- Compute pressures with SU2
- Compute displacements with ASTROS
- Displace CFD mesh, and compute pressures with SU2

session11/aeroelastic_Iterative_SU2_Astros.py

- Load aflr4AIM
- Load aflr3AIM
- Load su2AIM
- Load egadsTessAIM
- Load astrosAIM

- Create `capsBound` data transfers
- Generate meshes
- Fill `capsVertexSet`
- Iterate
  - Transfer displacements from ASTROS to SU2
  - Execute SU2
  - Transfer pressure from SU2 to ASTROS
  - Execute ASTROS

Iterative Data Transfer: Create Transfer

- Interleave AIM names in aimSrc and aimDest
- Initial value applied to Displacement to start iterations

session11/aeroelastic_Iterative_SU2_Astros.py

```
# Create the data transfer connections
transfers = ["upperWing", "lowerWing", "leftTip", "riteTip"]
for bound in transfers:
    myProblem.createDataTransfer(variableName   = ["Pressure", "Displacement"],
                                 aimSrc         = [su2.aimName, astros.aimName],
                                 aimDest        = [astros.aimName, su2.aimName],
                                 transferMethod = ["Conserve", "Interpolate"],
                                 initValueDest  = [None, (0,0,0)],
                                 capsBound      = bound )
```

- Generating mesh and `capsVertexSet`

Iterative Data Transfer: Execution

- Start iterations

session11/aeroelastic_Iterative_SU2_Astros.py

```
# Aeroelastic iteration loop
for iter in range(numTransferIteration):

    #Execute the dataTransfer of displacements to su2
    #initValueDest is used on the first iteration
    print ("\n\nExecuting dataTransfer \"Displacement\"......")
    for bound in transfers:
        myProblem.dataBound[bound].executeTransfer("Displacement")
```

- Execute SU2

```
    #Execute the dataTransfer of Pressure to astros
    print ("\n\nExecuting dataTransfer \"Pressure\"......")
    for bound in transfers:
        myProblem.dataBound[bound].executeTransfer("Pressure")
```

- Execute ASTROS

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Enhanced CAPS

EnCAPS

- Follow-on project funded by AFLR to enhance CAPS
  - Strive to minimize breaking changes (unavoidable)
- Restarting runs the same script (or control program) recycling previous data.
- A directory structure where the Problem Database contains all of the Analysis I/O Files.
- Parent/Child will be replaced with explicit links
- Improved error handling and error messages (developer vs. user errors)
- Deprecate `capsIgnore` in lieu of explicit geometry removal
- Full support for analysis execution
- Single UI (and integrated editor) for Geometry and Analysis

Final Thoughts

- ESP is freely available for download from acdl.mit.edu/ESP
- Based upon user requests, new and improved features are added continually
- Send bug reports to galbramc@mit.edu, haimes@mit.edu, or jfdannen@syr.edu
- Also send success stories to galbramc@mit.edu, haimes@mit.edu, or jfdannen@syr.edu

- Thank you for attending; send comments about the course to galbramc@mit.edu, haimes@mit.edu, or jfdannen@syr.edu