CAD Cleanup Practice

Capstone v9 Tutorial

Overview

Overview

Introduction

Capstone is an HPCMP CREATE™-MG product. This tutorial was generated by the HPCMP CREATE™-AV Quality Assurance team, with specific intentions of being applied to AV-related cases, however, it could be applicable in other areas as well.

Why this Tutorial?

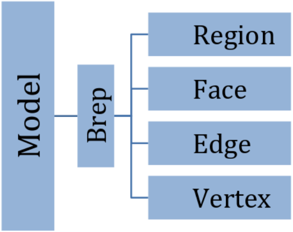
- Objectives:
  - Gain familiarity with various features/functions inside of Capstone
  - Practice cleaning up "dirty" CAD
- Potential Applications:
  - CAD cleanup

Notes Going Forward:

- This tutorial assumes you have completed introductory training either through the Intro Video or Workflow Intro (In the AVQA Section) tutorial
- If you have not, please check out the latest **Documentation** page to download the video/tutorial

Topology Definitions

Capstone uses the following Topology model to describe geometry:



Model

- Total grouping of all Breps and meshes

Brep (Boundary Representation)

- A grouping of geometry entities

Region

- A water-tight volume defined by connecting faces where the volume mesh will be generated

Face

- Surface defined by a closed set of edges

Edge

- Curve bounded by 2 (or 1 if self looping) vertices

Vertex

- Point defined by x,y,z location

Workflow

1. Geometry Setup
   - Import or create geometry
     - Can be CAD or Discrete
   - If CAD, then "clean" to make water-tight
     - utilize the **Edit** > **Basic Cleanup** menu
   - Fluid Volume Region Creation
     - Regions are where the volume mesh will be created
     - Define the fluid volume to be solved on
2. Mesh Setup
   - Set **Analysis** if not already defaulted (can set in **File** > **Preferences**)
   - Work your way down the **Attributes Tab**
     - For example, set up Global Sizing, Topos Sizing, Boundary Layers, Periodicity and any other mesh settings as desired
   - Set up both Surface and Volume mesh settings before meshing for highest mesh quality/consistency

Workflow Continued

3. Generate Meshes
   - Generate a Surface Mesh
     - Inspect the mesh (visually and/or using **Mesh** > **Mesh diagnostics** or **Detect defects and heal**) and make any necessary changes
   - Generate a Volume Mesh
     - Inspect the mesh again
       - Utilize **Mesh** > **Mesh crinkled cutplanes** to visualize the volume cells
4. Export Mesh
   - Create mesh Properties (like Patches) if desired
   - **File** > **Export Mesh**

Overview

Helpful Functions Overview

There are many cleanup functions in Capstone. For your reference, here are brief summaries for some of the most helpful ones:

Edit > **Stitch Topos** and **Breps** > **Stitch Brep**

- Used to merge common entities that are duplicated
- Example: When two faces share a common geometric edge, but topologically there are 2 edges between them. Use these functions to stitch them into one, making the connection between the faces "water-tight"
- **Stitch Topos** is used on individual entities the user selects, **Stitch Brep** applies a generic stitching routine to the entire Brep

Faces > **Untrimmed (or Trimmed) Face Creation**

- Used to untrim a surface beyond its existing edges, or trim a face using a set of existing edges

Edges > **Merge Connected Edges**

- Used to combine 2 connecting edges, that share only 1 vertex, into 1 edge.

Faces > **Join Faces**

- Used to combine 2 adjacent faces into 1 face. Works best if only 1 edge is shared.

Faces > **U/V Face Split**

- Used to split a face in U/V coordinate space.

Water-tight Geometry

The following slides will discuss various (but not all) ways to use Capstone to get surfaces to intersect properly so they can be water-tight when they have shared edges geometrically but not topologically. Meaning, there are duplicate edges that share the same geometric (xyz) space, but each edge is only associated topologically with one of the adjacent faces.

The best option for cleaning this up is **Edit** > **Stitch Topos**. It is the most robust and gives the user the most control. For Stitch Topos to work on edges keep in mind that the edges must share the same vertices. So you may need to stitch the duplicate vertices first.

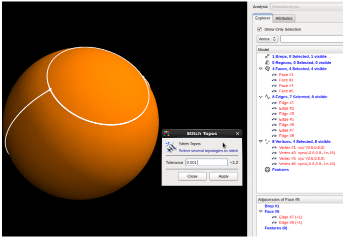
Another option you can try is **Brep** > **Stitch Brep**. This does what Stitch Topos does, but on a global level (the entire Brep not just the individual edges/vertices you select). This one can be dangerous as the results aren't always as desired, but it is worth trying if you have a large number of merges required.

The last option we'll discuss is utilizing the **Faces** > **Trimmed (or Untrimmed) Face Creation** functions that Capstone provides. This option works fairly robustly, but requires a few extra steps/clicks.

Stitch Topos

Stitch Topos is used to combine vertices or edges that lie on top of each other geometrically. Load trimming.cre and use Stitch Topos to make it water-tight.

- Switch to **Display Type** > **Usage**
- The yellow edges indicate "Edges Used Once" and if you were to try to select them you would get the drop-down indicating you have two choices in the same geometric location
- **Edit** > **Stitch Topos** and rubber-band select the area where the 2 edges are overlapping (and yellow) on the "top" face, then hit Apply



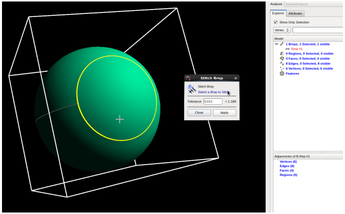
- This will combine the extra edges and leave you with just 1 edge per side!
- If you are not happy with the results, or need finer control, you can manually select 2 topologies at a time and stitch them individually
- This will give you a water-tight sphere!; Any time sucessful merging/stitching occurs Capstone automatically attempts to create Regions on closed geometry

Stitch Brep

Stitch Brep can be used to allow the code to search the Brep for overlapping edges/vertices and stitch them automatically. This option is very helpful if a large number of items need to be stitched, however, it can also stitch things that you may not have wanted to, so use it carefully!

Re-load trimming.cre for an example of how to use Stitch Brep.

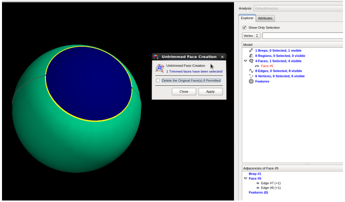
- **Breps** > **Stitch Brep**
- Select the Brep and hit apply
- You now have a water-tight geometry and a region was automatically generated!



Untrimmed Face Creation

To practice this function, re-load trimming.cre

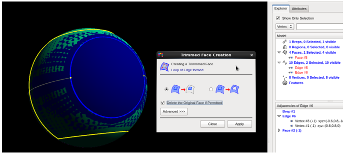
- Switching to **Display Type** > **Usage** shows the “top” face isn’t connected to the rest of the sphere
- **Faces** > **Untrimmed Face Creation**. Select the “top” (Face 5), then hit Apply
- **Edit** > **Delete Topologies**, Select the original “top” (Face 5), hit Lower Entities then hit Apply (This will delete the face, and the edges/vertices associated with it)



The next slide will show you how to trim the face to make a water-tight region.

Trimmed Face Creation

- **Faces** > **Trimmed Face Creation**. Check Delete the Original Face if Permitted, select the new face (Face 3) and Edges 5 and 6 (it should auto-complete once one edge is selected), then hit Apply



Notice that the "original face" (Face 3) wasn't deleted, despite the option we checked. This is because a region was automatically created during the trimming process that included this face! But why, since it isn't topologically connected?!

Anytime a trim, stitch, or merge occurs Capstone automatically attempts to create a region when a set of topologically connected faces, all in the same Brep, encloses a closed finite volume. Any topologically unconnected geometry that is fully contained within the closed volume and that is part of the same Brep will be embedded in the Region!

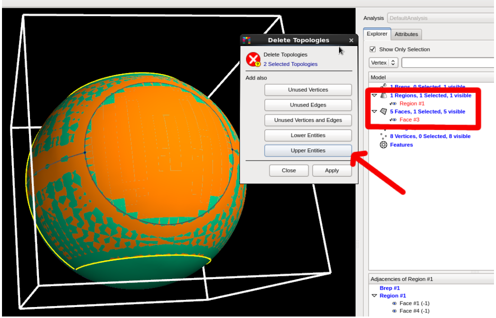
In this case, the trimming created a fully topolocially connected sphere, and the original face (Face 3) is still in the same Brep and "fully contained" within the closed volume of the topologically connected sphere, therefore it got added to the Region...and this brings us to our next lesson: How to Delete Topologies

How to Delete Topologies

Topologies can only be deleted if they are NOT used by higher level entities: Faces cannot be deleted that are used by a Region. Edges cannot be deleted that are used by a Face or a Region. Vertices cannot be deleted that are used by an Edge, a Face or a Region.

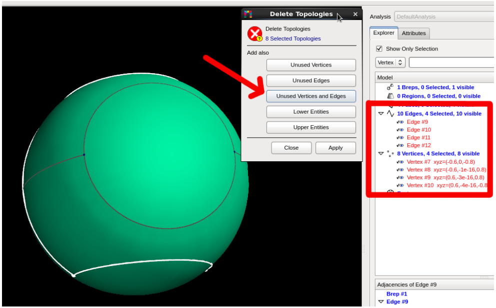
So, to delete the unwanted Face 3, we must also delete the region that it is associated with. (Don't forget, you can always use the Explorer Tab to right-click "Select Up or Down" to select/view the connections, or simply highlight and view the connections in the Adjacencies Panel)

- **Edit > Delete Topologies**. Select Face 3, then hit Upper Entities and then hit Apply



Delete Unused and Region Creation

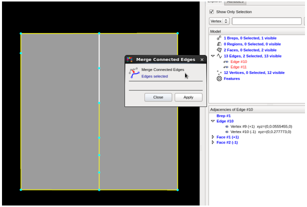
- **Edit** > **Delete Topologies**. hit Unused Vertices and Edges and then hit Apply
- This deletes the remaining edges/vertices that were part of Face 3
- **Solids** > **Region Creation from Faces**, select any face of the sphere and hit Apply
- You now have a water-tight sphere!



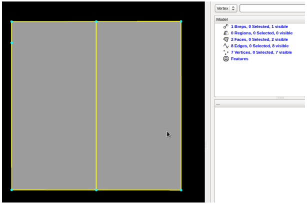
Merge Connected Edges

To practice this function, load merging.cre

- **Edges** > **Merge Connected Edges**
- Select the 2 adjacent edges you wish to merge and hit apply
- It is best to start with the largest and work your way towards the smallest edge
- Alternatively, if the edges are linear or perfectly tangential, you can select all of them at once and merge them in one step



- Repeat the process until you only have 1 edge between the two adjacent faces
- If joining the faces, having only 1 edge between them is the most robust way of doing so, hence why we merged the edges

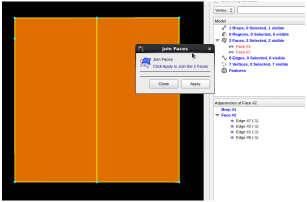


Join Faces

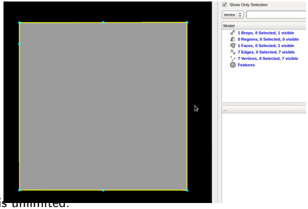
To practice this function, you can either start from where you left off with **Merge Connected Edges** or you can start from scratch with merging.cre again.

The instructions below will work in either case. This geometry is simple enough that the edges between the faces did not need to be merged as shown on the previous slide for the joining to work properly.

- **Faces** > **Join Faces**
- Select the 2 faces and hit apply



- The final result will be one face

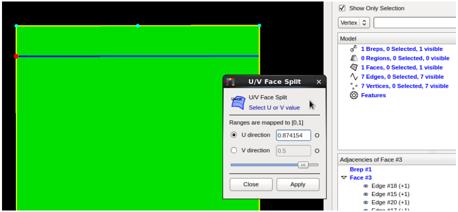


U/V Face Split

This function can be used to split a face along a desired U/V parametric line of the geometry. Continue on with the geometry from the previous slide, after the faces have been joined.

- **Faces** > **U/V Face Split**
- Select the face and notice the preview line
- You can change where the cut will be by moving the slider, entering a manual U/V Parameter, or using the probe
- For this case, we will use the existing vertex on the left edge and the probe to do the cut

- Switch to U direction
- Set the probe to coordinates and probe select (Ctrl or Alt +LMB) the vertex shown below
- Hit Apply



When Stitching/Merging Fails

Here is a checklist for when Stitching/Merging or any other operations fail:

1. Are the geometry entities in the same Brep?
   - This is required for non-Boolean Operations
   - To fix this, utilize Boolean Union/Non-Regularized Union, or Merge Breps
2. Does a Region exist?
   - Edges/Vertices cannot be Stitched with Edges/Vertices that are part of an existing Region
   - Delete the Region and try the stitch/merge again
3. Does a set of topologically connected faces enclosing a finite volume exist?
   - Normally this only occurs if you previously had a Region, but deleted it
   - The same problem as number 2, above, is occuring, because as the stitch/merge is attempted Capstone is automatically creating a region on the topologically connected faces and then it is failing to merge/stitch because of the “existing” Region (even though the Explorer Panel shows 0 Regions)
   - To fix this, delete a face (that will be easily re-created) that is part of the topologically connected set, thus removing any/all topologically connected finite volumes. (Most likely this will be an outer boundary box face.)

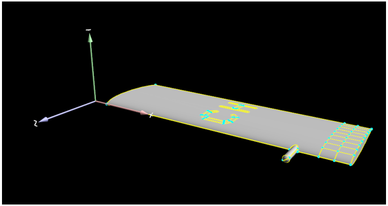
When Stitching/Merging Fails (continued)

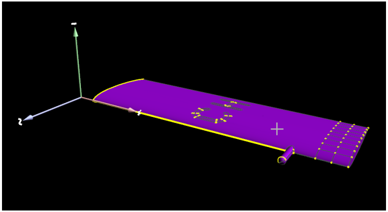
5. Are outer box/farfield faces present in the same Brep?
   - In many operations including stitching, the SMLib geometry kernel attempts to create a region, but it gets confused if the faces in the Brep are non-manifold (not all topologically connected). This can cause the operation to fail without any indication of what went wrong. The solution is to delete the outer faces or split them into a separate Brep.

Overview

Geometry Provided

The "dirty" CAD file is provided (originally an iges file) as dirtyCAD.cre. Load the file into Capstone. It should look like the pictures below (**Display Type** > **Usage** on right):





The CH logo is on the "upper" surface of the airfoil (though it is symmetric)

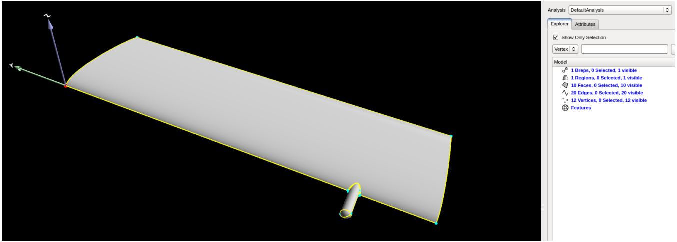
Included with the tutorial download is an Answer Video that goes through step by step how to complete the cleanup. Please reference it as needed if you get stuck! There is also a cleanCAD.cre file which is the final state of the clean geometry, including a volume mesh.

Overview

CAD Cleanup Instructions

The following list of instructions will guide you when cleaning up the CAD

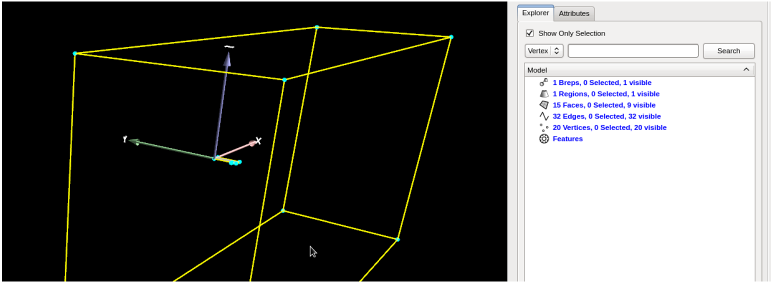
- Make the grid xByRzU, with the root LE vertex at 0,0,0
- Create 1 connected face across the upper surface of the wing
  - Remove the CH logo
  - Remove the small faces near the wing tip
  - Use the functions from the previous slide as necessary
- Utilize **Edit** > **Basic Cleanup**
  - Remove/replace anything that fails Edge/Topos Validity
  - Remove any unwanted Small Edges/Faces
  - Make it watertight by monitoring the Closure or **Display Type** > **Usage**
- Once satisfied with geometry cleanup, create a region on the wing
- The final cleaned up geometry should look like this:



Fluid Volume Instructions

Now that the geometry is cleaned, create an outer boundary box and the fluid region

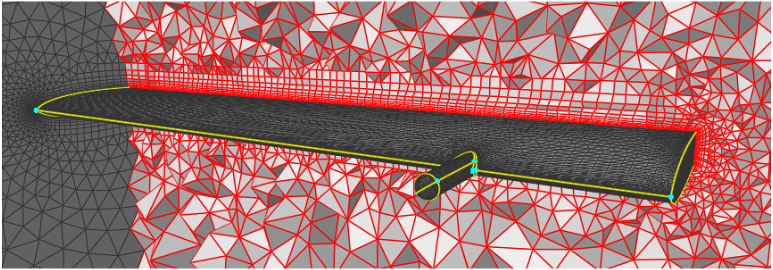
- Create a boundary box with a symmetry plane with dimensions:
  - 10 span lengths forward and aft
  - 5 span lengths to the side, up, and down
- Create the fluid volume region
  - Utilize the **Breps** > **Boolean Operations** so you end up with 1 Brep and 1 Region (the fluid volume region)



Mesh Instructions

Now that the CAD is cleaned, and the fluid volume created, it is time to create the mesh. First, add Kestrel Analysis then size the geometry as follows:

- The smallest outer boundary edge should have 10 cells across its length
- Sizing on the Wing Faces of 4% of chord
- Sizing on the Wing Tip Face of 1% of chord
- Sizing on the Probe of 10% of its diameter
- Utilize Edge Boundary Layers
  - Leading and trailing edge chord-wise spacing of .04% chord for 1st Layer
- Utilize Face Boundary Layers
  - Assume Reynolds number of 1e6, y+=1, and the chord as the reference length



Conclusion

Congratulations on finishing your mesh! Hopefully, it looked something like the last picture and don't forget cleanCAD.cre is included for you to inspect and compare.

For more help relating to Capstone or other CREATE products please check out:

Capstone Website
Capstone User Online Forum
CREATE Website
CREATE-MG Quality Assurance Support
CREATE-AV Quality Assurance Support