

Using Faceted Geometries for Analysis and Design



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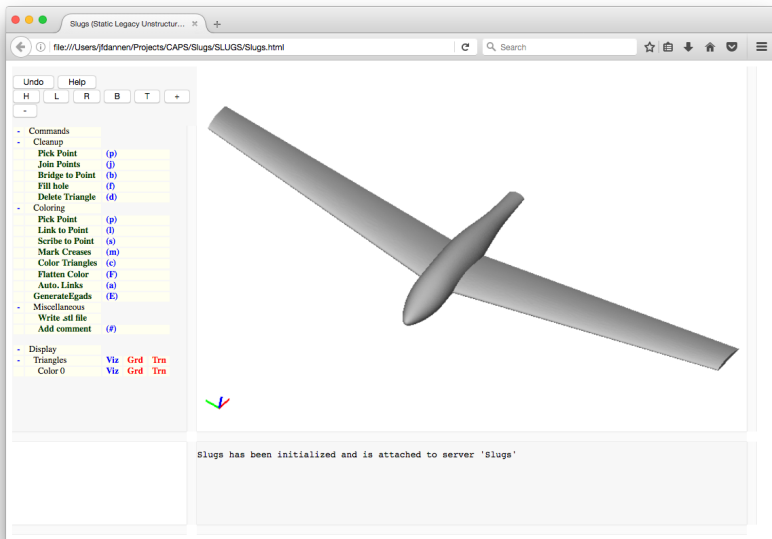
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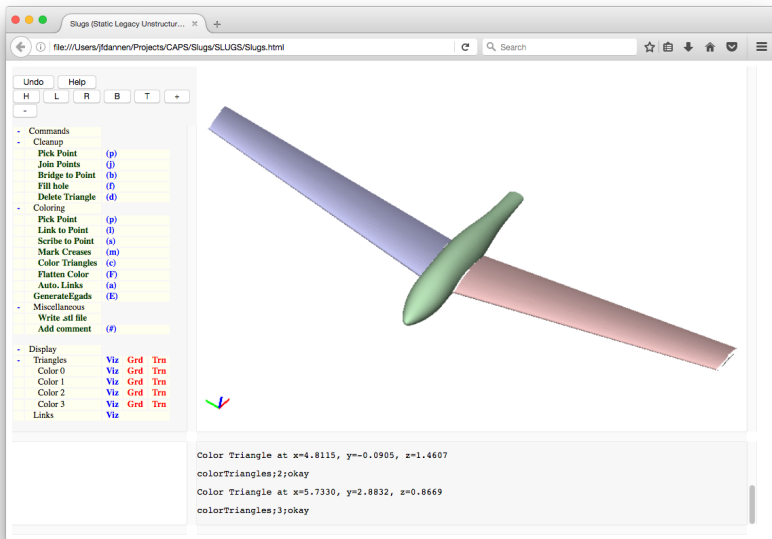
- Background
- Static representation via **Slugs**
- Parametric representation via **Plugs**
- Summary and availability

- Many analysis and design tasks start from a previous configuration that is (unfortunately) defined by tessellated surfaces
 - these definitions sometimes come from legacy CAD tools that are no longer supported
 - these definitions sometimes come from laser scans of a real configuration
- This results in faceted surfaces that yield less-than-desirable results when used in CFD and FEM tools

- Import the cloud of points by:
 - inputting a completely disconnected set of points
 - extracting the points (and triangles) from an STL file
 - reading an IGES or STEP file and tessellating the trimmed surfaces
- Separate the points into “colors”, where each color represents a part of a component
 - all colors should be bounded by 2, 3, or 4 sides
- Create Boundary Representation (Brep) with:
 - Nodes at any location where the adjacent triangles have more than 2 colors
 - Edges at any location where the adjacent triangles have only two colors and are least-square-fit with B-spline curves
 - Faces in the regions of a single color (with 2, 3, or 4 Edges) and are least-square-fit with B-spline surfaces



- Is easiest when points are connected with triangles
- Mark triangle sides with “creases” (where dihedral angle exceeds a user-specified tolerance)
- Mark triangle sides on shortest side-path between two points
- Scribe triangles on “straight” line between two points and mark the new sides



The screenshot shows a software application window titled "Slugs (Static Legacy Unstructur...". The address bar displays the file path: "file:///Users/jdannen/Projects/CAPS/Slugs/SLUGS/Slugs.html". The interface includes a menu bar with "Undo" and "Help", and a toolbar with buttons for "H", "L", "R", "B", "T", and a dropdown arrow. A command palette on the left lists various actions:

- Commands
 - Cleanup
 - Pick Point (p)
 - Join Points (j)
 - Bridge to Point (b)
 - Fill hole (f)
 - Delete Triangle (d)
 - Coloring
 - Pick Point (p)
 - Link to Point (l)
 - Scribe to Point (a)
 - Mark Creases (m)
 - Color Triangles (c)
 - Flatten Color (F)
 - Auto. Links (a)
 - GenerateEgads (E)
 - Miscellaneous
 - Write .stl file
 - Add comment (#)
 - Display
 - Triangles
 - Color 0 Viz Grd Trn
 - Color 1 Viz Grd Trn
 - Color 2 Viz Grd Trn
 - Color 3 Viz Grd Trn
 - Links Viz

The main view displays a 3D model of a sword with a green blade and a red hilt. A small color selection tool is visible in the bottom left of the main view. The console window at the bottom shows the following commands:

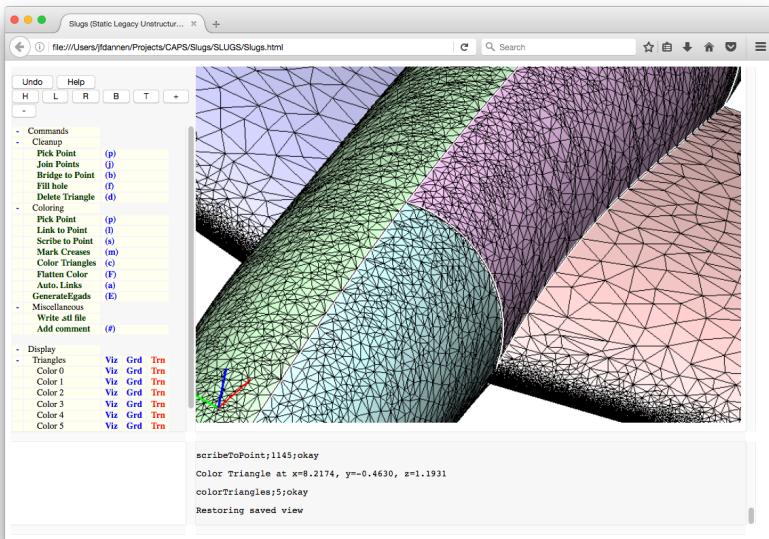
```
Color Triangle at x=4.8115, y=-0.0905, z=1.4607
colorTriangles;2;okay
Color Triangle at x=5.7330, y=2.8832, z=0.8669
colorTriangles;3;okay
```

The screenshot shows a web browser window with the URL `file:///Users/jdannen/Projects/CAPS/Slugs/SLUGS/Slugs.html`. The application interface includes a menu bar with `Undo` and `Help`, and a toolbar with `H`, `L`, `R`, `B`, `T`, and a minus sign. A command palette on the left lists various actions:

- Commands**
- Cleanup**
 - Pick Point (p)
 - Join Points (j)
 - Bridge to Point (b)
 - Fill hole (f)
 - Delete Triangle (d)
- Coloring**
 - Pick Point (p)
 - Link to Point (l)
 - Scribe to Point (a)
 - Mark Creases (m)
 - Color Triangles (c)
 - Flatten Color (F)
 - Auto. Links (a)
 - GenerateEgads (E)
- Miscellaneous**
 - Write stl file
 - Add comment (#)
- Display**
 - Triangles
 - Color 0 Viz Grd Trn
 - Color 1 Viz Grd Trn
 - Color 2 Viz Grd Trn
 - Color 3 Viz Grd Trn
 - Color 4 Viz Grd Trn
 - Links Viz

The 3D view shows a curved structure with a wireframe mesh. The sides are colored: purple, green, cyan, and pink. A red line is visible on the green side. The console at the bottom shows the following commands and their outputs:

```
pickPoint;1137;okay
Link Point at x=3.6654, y=-0.0137, z=1.3573
linkToPoint;1137;okay
Restoring saved view
```

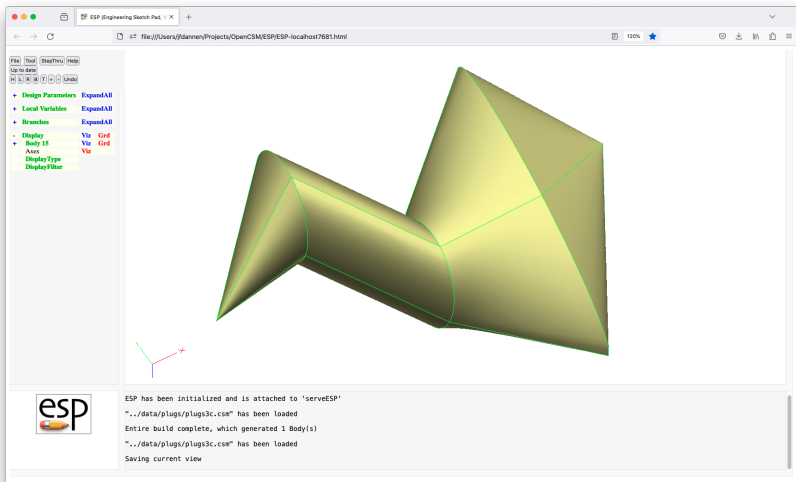



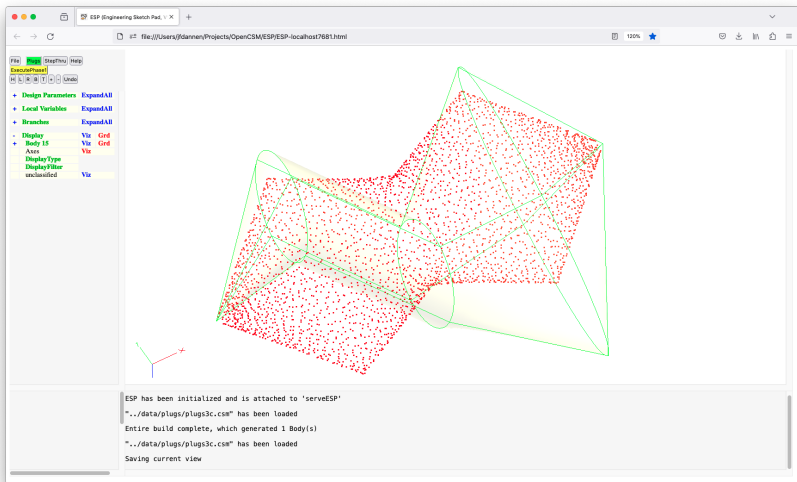
The screenshot shows a web browser window with the URL `file:///Users/jdannen/Projects/CAPS/Slugs/SLUGS/Slugs.html`. The application interface includes a menu bar with 'Undo' and 'Help', and a toolbar with 'H', 'L', 'R', 'B', 'T', and a minus sign. A command list on the left is organized into categories: 'Commands', 'Cleanup', 'Coloring', 'Miscellaneous', and 'Display'. The 'Coloring' section is expanded, showing options like 'Pick Point', 'Link to Point', 'Scribe to Point', 'Mark Creases', 'Color Triangles', 'Flatten Color', 'Auto. Links', and 'GenerateEgads'. The 'Display' section is also expanded, showing 'Triangles' and 'Color' options (Color 0 through Color 5), each with 'Viz', 'Grd', and 'Trn' sub-options. The main 3D view displays a wireframe mesh of a curved surface, with several triangles highlighted in different colors: purple, green, cyan, and pink. A small blue and red line is visible on the mesh. The command console at the bottom shows the following text:

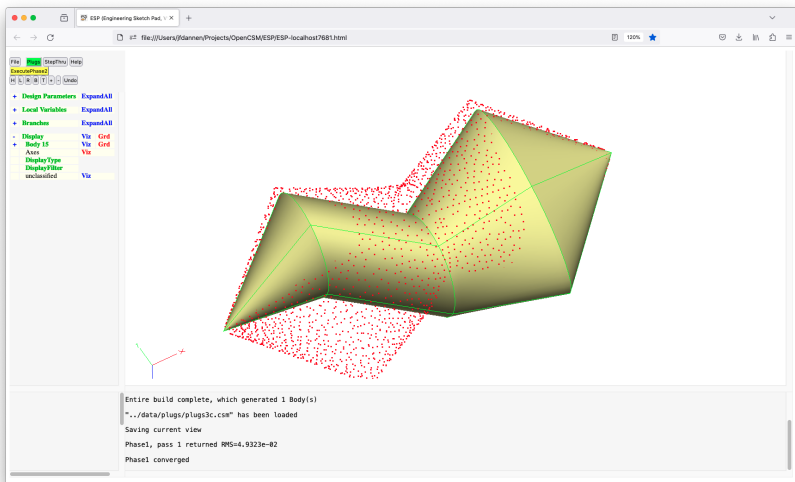
```
scribeToPoint;1145;okay
Color Triangle at x=8.2174, y=-0.4630, z=1.1931
colorTriangles;5;okay
Restoring saved view
```

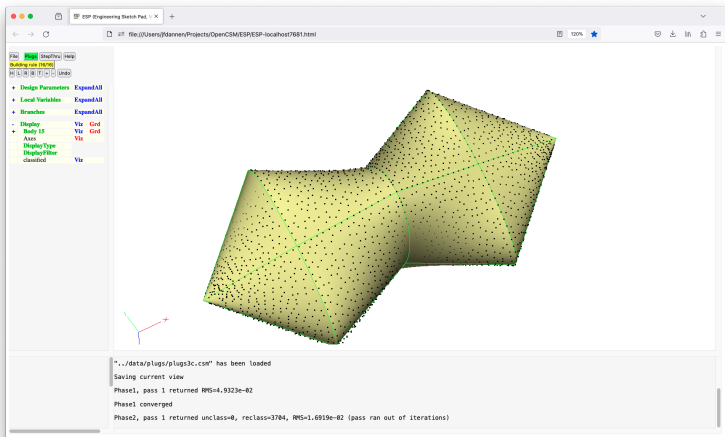
- Advantages
 - no need to start with a parametric model
 - can be applied to a single Edge or Face
 - fitting process is very fast
- Disadvantages
 - produces a non-parametric (static) model
 - coloring points can be time-consuming
 - Faces are limited to 2-, 3-, or 4-sides (no trimming)

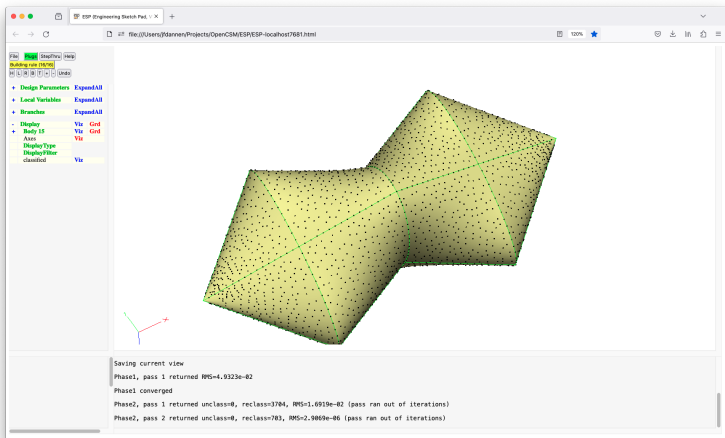
- 1 Generate a parametric model, with several design parameters (DESPMTRs);
- 2 Phase 1: Change the DESPMTRs so that the bounding boxes of the cloud of points and the model match;
- 3 Mark all the points in the cloud as unclassified;
- 4 Phase 2: Perform several passes:
 - For each point in the cloud
 - determine to which Face (if any) it should be classified
 - if no cloud points are classified differently than in the previous pass, stop Phase 2
 - Modify the DESPMTRs to least-squares minimize the distances between the classified cloud points and their respective Faces.
 - uses Levenberg-Marquardt technique
 - Go back for next Phase 2 pass

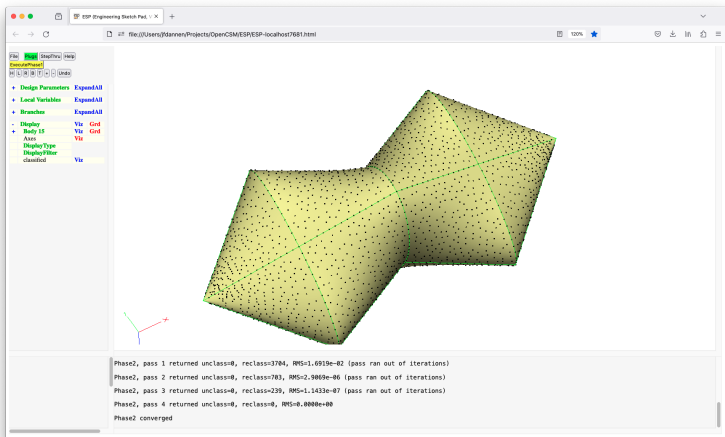












- Advantages
 - produces a parametric model
 - points do not need to be classified
 - fitting process is very fast
- Disadvantages
 - user must start with a parametric model that is “close-enough” to the cloud of points

- Given a cloud of points:
 - **Slugs** can be used to generate a static (non-parameterized) model
 - **Plugs** can be used to adjust design parameters to match the unclassified points
- Both tools are part of the **ESP** distribution, which is an open-source project (using the LGPL 2.1 license) that is distributed as source, and is available from <https://acdl.mit.edu/ESP>.