Python API: Customization and Visualization

1. TiGL Workshop, September 11 / 12, Cologne

Martin Siggel
German Aerospace Center

DLR

Outline

- How to modify TiGL-internal shapes
- Affine transformations (scaling, translations, rotations …)
- Boolean Operations
- Visualization with the Qt-based SimpleGui
- 3D rendering inside a Jupyter notebook
- Practical Session

Motivation

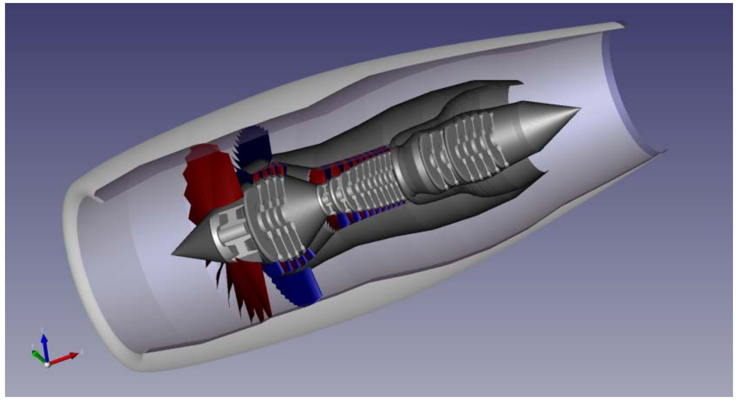
- Two use cases:

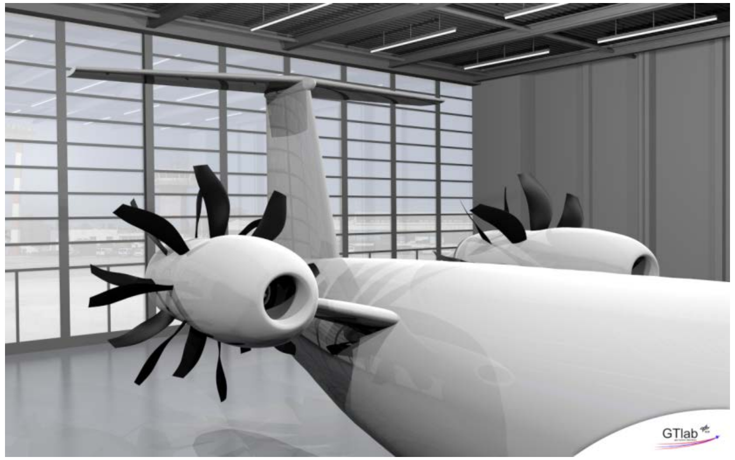
    1. Add new geometric components that are not included in TiGL

    2. Modify/improve existing components

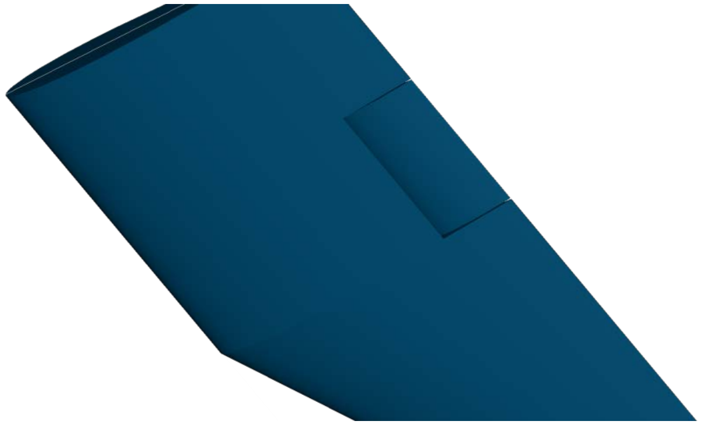
- First is straight forward: Just read out CPACS values and model your own geometry

- Second: How to modify the shapes? Can something happen?





Modification of TiGL shapes

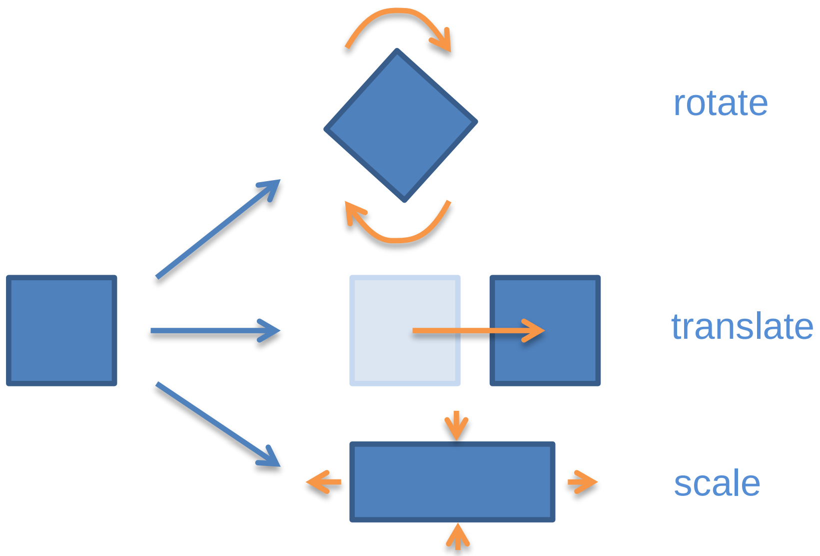


- Assume, you want to model wing flaps or wing caps
  - ➢ The wing shape has to be altered
- TiGL is not designed to change the internal shapes from outside
- TiGL is not designed to change the internal shapes from outside
- Still, this is possible!
- Each CNamedShape object has a `.Set(shape)` method:

```
# create new shape of modify the existing
new_shape = ...

# now set the changed loft to the wing
wing.get_loft().Set(new_shape)
```

Affine Transformations
How to move, resize, rotate shapes

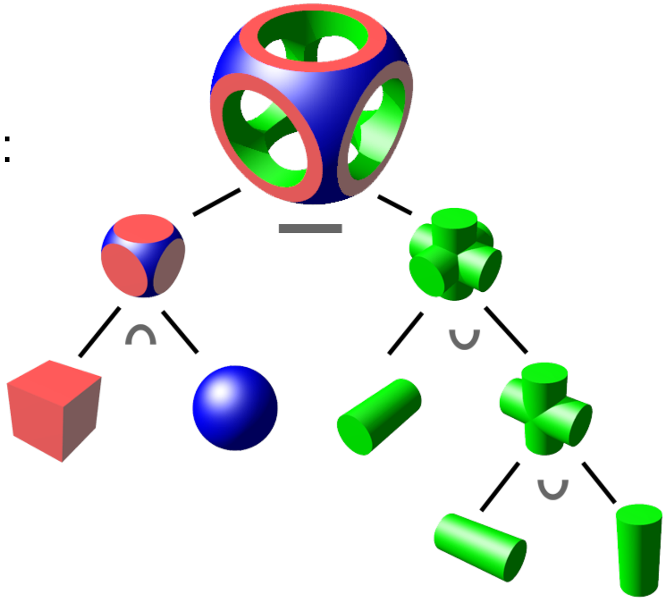


- Shapes can be modified after creation
- Basic modification is affine transformation
- Use methods from class **tigl3.geometry.CTiglTransformation**. First build transformation matrix. Order matters!

Method	Description
`.add_translation(x, y, z)`	Move the shape
`.add_scaling(sx, sy, sz)`	Scale the shape along x, y, z axes
`.add_rotation_x(angle_degree)`	Rotate around the x axis
`.add_rotation_y(angle_degree)`	Rotate around the y axis
`.add_rotation_z(angle_degree)`	Rotate around the z axis
`.add_mirroring_at_xyplane()`	Mirror at the x-y plane
…	

- Transform the shape: `transformed_shape = trafo.transform(shape)`

Boolean Operations
The tigl3.boolean_ops module



- Basic build blocks for constructive solid geometry

- Assume, we have two Shapes A and B. Typical Boolean Operations (BOPs) are:
  - Union: $A \cup B$
  - Difference: $A \setminus B$
  - Intersection: $A \cap B$

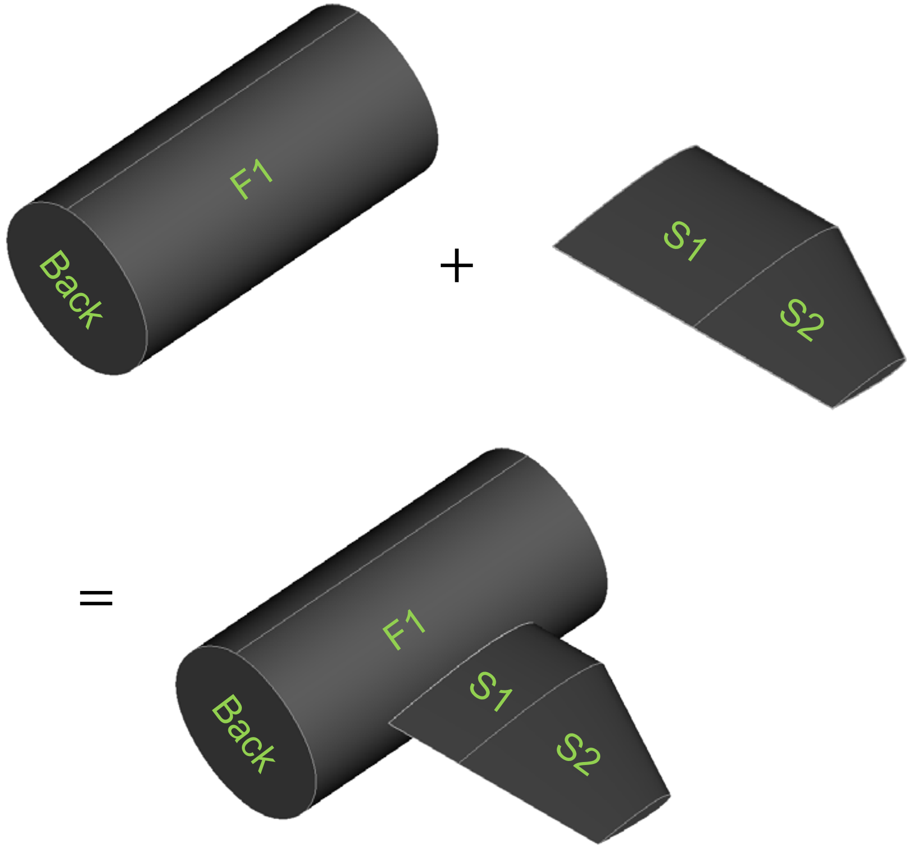
- Boolean Operations on B-Spline / NURBS are hard!
  Try to avoid them if possible.

- OpenCASCADE offers BOPs, but:
  1. Unfortunately suffer from robustness issues
  2. Don‘t track shape modification (which face of a whole aircraft is from the wing?)

- TiGL BOPs wrap those from OpenCASCADE but add shape modification tracking!

Boolean Operations
The tigl3.boolean_ops module

- Faces are modified / trimmed by BOP
- Difficulty: Figure out, what face of the result is created from which input face
- TiGL BOPs do this for you!
  - Face names are assigned automatically by TiGL
  - TiGL keeps track of the CSG graph
- The following BOP classes from tigl3.boolean_ops can be used:
  - `CFuseShapes`: Boolean union of multiple shapes at once
  - `CMergeShapes`: Similar to CFuseShapes, but only for shapes that share adajcent faces
  - `CCutShape`: Boolean Difference
  - `CGroupShape`: No true BOP. Just a group of shapes.



Boolean Operations
Example

1. Lets cut away the internal part of the wing inside the fuselage:

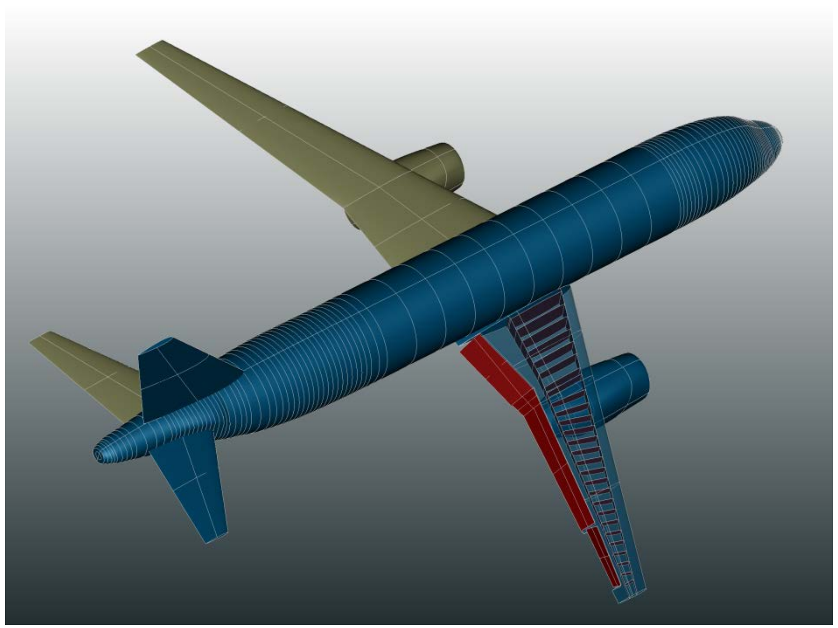
```
from tigl3.boolean_ops import CCutShape
cutted_wing = CCutShape(wing.get_loft(), fuselage.get_loft()).named_shape()
```

2. Now, lets fuse fuselage and both wings

```
fused_aircraft = CFuseShapes(fuselage.get_loft(),
                             [wing.get_loft(), wing.get_mirrored_loft()]).named_shape()
```

Visualization

- Nice images have often more impact than complicated algorithms!
- TiGL Viewer was initially developed only for debugging purposes!
- Visualization help debugging geometric algorithms or during modelling of complex shapes
- Good news:
  - PythonOCC comes with a 3D viewer, that can be also integrated into own user interfaces!
  - Also experimental renderer for Jupyter notebook



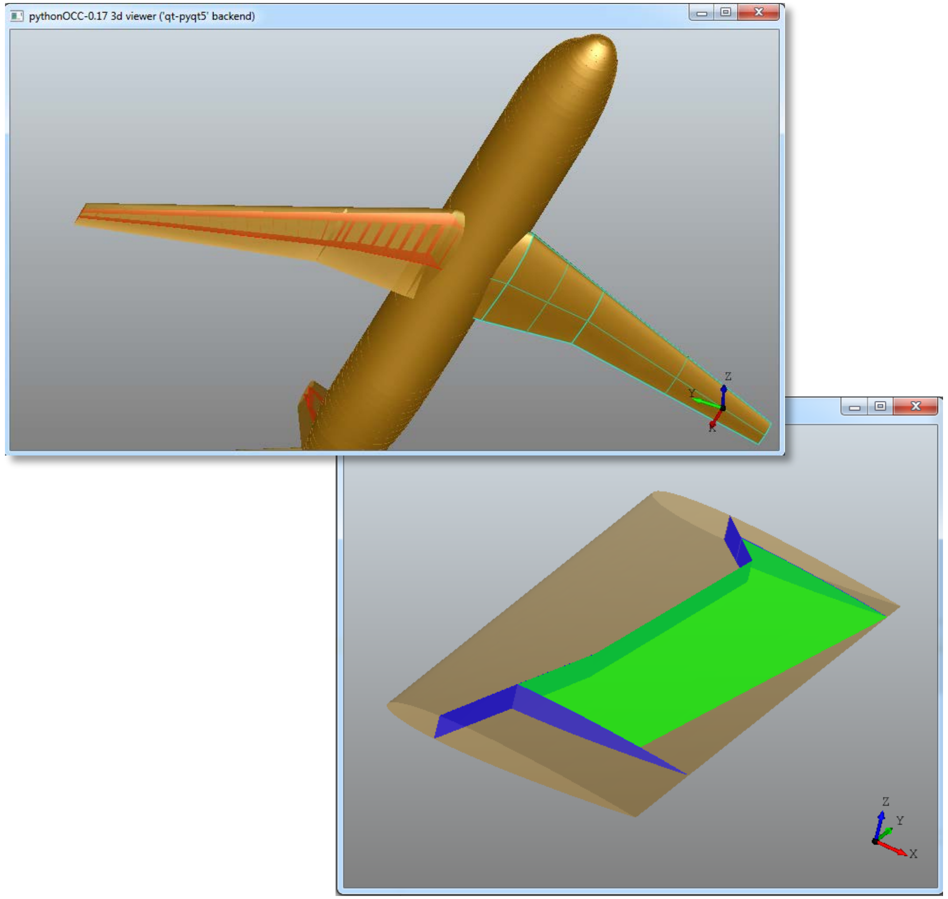
SimpleGui: A Qt-based 3D Viewer

- Draw OpenCASCADE shapes (TopoDS_Shape) with only a few lines of code

- Can be integrated in larger user interfaces

- Possible, to add callbacks to perform actions

- Features:
  - Selection of Colors
  - Transparency
  - Set material of shape
  - Draw Textures
  - Theoretically, also custom Shader code



SimpleGui: A Qt-based 3D Viewer

To open Viewer window and draw some shapes, we need 3 steps

1. Create the viewer and store it as viewer

```
from OCC.Display.SimpleGui import init_display
viewer, start_display, add_menu, add_function_to_menu = init_display()
```

2. Draw a shape. Notice, we must access the TopoDS_Shape from the CNamedShape!

```
viewer.DisplayShape(wing.get_loft().shape(), update=True)
```

   If update is True, the viewer will draw the shape immediately.

3. Start the event loop of the viewer to interact with the visualization:

```
start_display()
```

SimpleGui: A Qt-based 3D Viewer
More control

- The DisplayShape() method has several optional parameters to control transparency, color and texture:

```
DisplayShape(shapes, material=None,texture=None, color=None, transparency=None, update=False)
```

- Color can be
  - Either a string: e.g. „red“
  - A color value from the OCC.Quantity package: e.g. `OCC.Quantity.Quantity_NOC_GREEN`

- Material is of type **Graphic3d_NameOfMaterial** from OCC.Graphic3d:
  - `Graphic3d_NOM_CHROME, Graphic3d_NOM_ALUMINIUM, Graphic3d_NOM_METALIZED, Graphic3d_NOM_SHINY_PLASTIC, Graphic3d_NOM_STONE …`

- Texture: Why not try to figure it out?

SimpleGui: A Qt-based 3D Viewer
More control

- The viewer has many methods, which can be grouped as follows:
  - Mouse interaction
  - Selection of shapes
  - Modify eye + look-at position
  - Functions to add callbacks

- Find out, what the viewer can do by using the help

```
help(OCC.Display.OCCViewer)
```

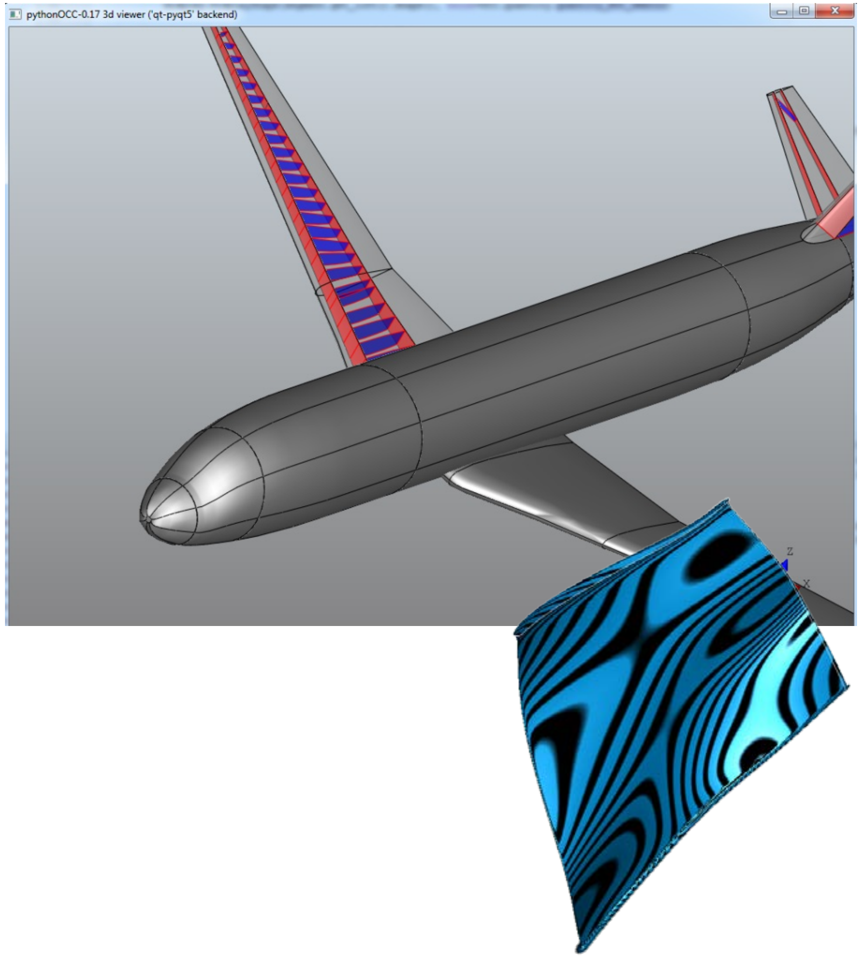
- Very useful command: Fit displayed objects to screen

```
viewer.FitAll()
```

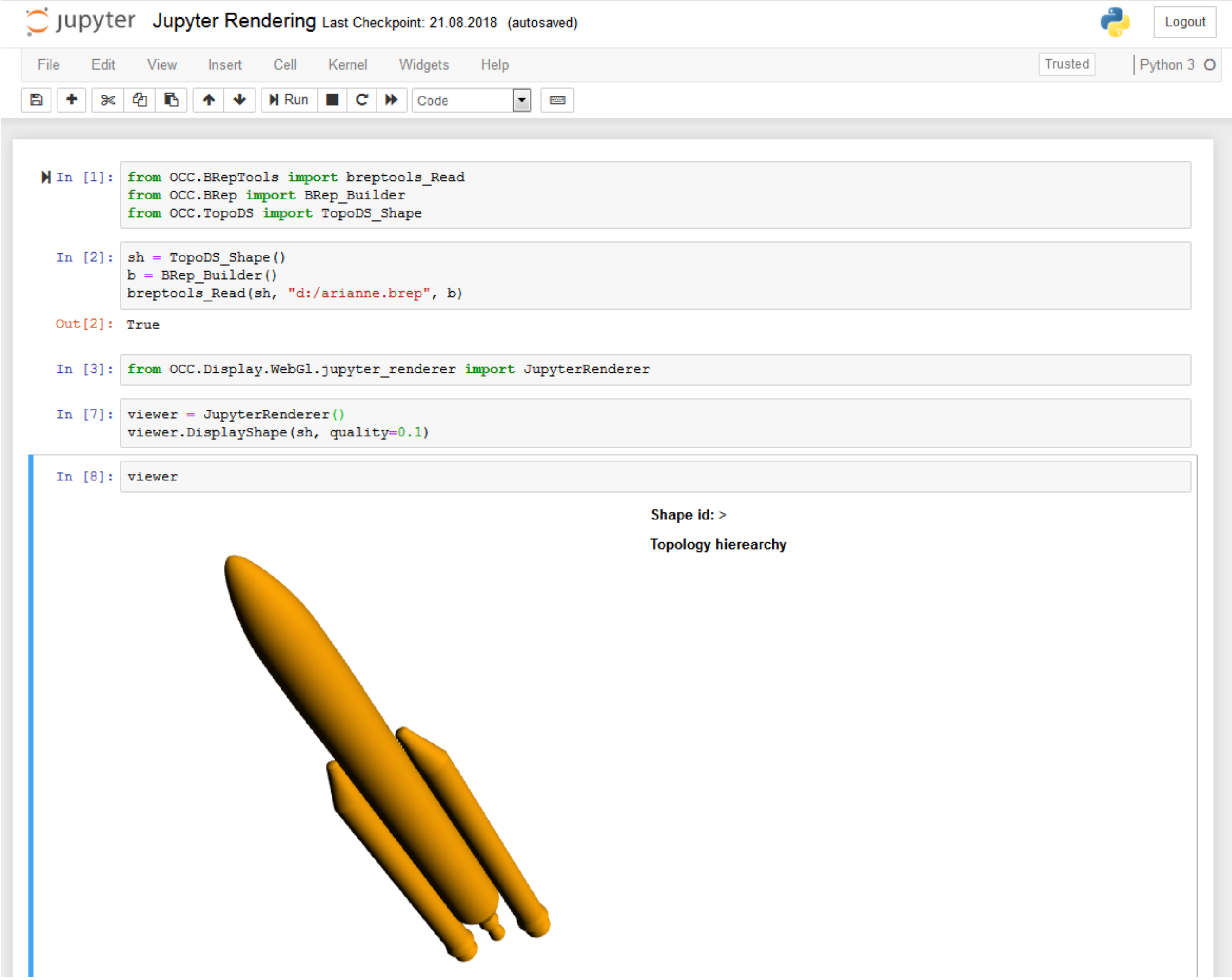
SimpleGui: A Qt-based 3D Viewer
Even more control

- Much more can be adjusted via **the Interactive Context** of the viewer.
- The context **manages** the **3D scene and all graphic attributes** (line colors, shading colors, custom shader code …)
- Access interactive context: `viewer.Context`
- Look into the OpenCASCADE documentation for much more control and customization:

  https://www.opencascade.com/doc/occt-7.3.0/overview/html/occt_user_guides__visualization.html



Visualization inside Jupyter Notebook



Visualization inside Jupyter Notebook

- Jupyter gives you a nice **interactive python shell** inside your browser

- Using **WebGL** and **Javascript**, it is possible to render 3D geometries on web pages

- The Jupyter renderer is
  - An **experimental** feature of pythonOCC
  - **Back-ported** into our conda packages from the latest source
  - Not as mature and has **less features** than the other viewer!

- Still, it is fun…

Visualization inside Jupyter Notebook
Howto

Again, we need 3 steps

1. Create the viewer

```
from OCC.Display.WebGl.jupyter_renderer import JupyterRenderer
viewer = JupyterRenderer()
```

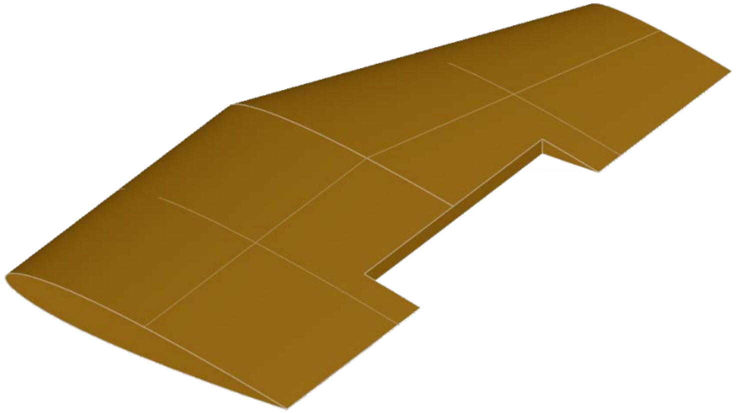
2. Add shapes to the viewer

```
viewer.DisplayShape(wing.get_loft().shape(), quality=0.1)
```

3. Render the viewer window

```
viewer
```

Practical Session: Customization Visualization



- Now it‘s your turn

- Goal: Model, export and visualize a wing flap cutout:
  You can do this, by subtracting a box from the wing.

- Possible Tasks:
  1. Open exercise 2 from course material inside a Jupyter notebook
  2. Access the first wing
  3. Create a box
  4. Move the box to the desired position
  5. Use TiGL’s Boolean operations to cut out the box
  6. Apply the result to the wing component
  7. Export the **fused** airplane to STEP format with: `tigl_handle.exportConfiguration`
  8. Visualize the result with the SimpleGui
  9. Try to change color etc
  10. Visualize the result directly in the Notebook

Any Questions?