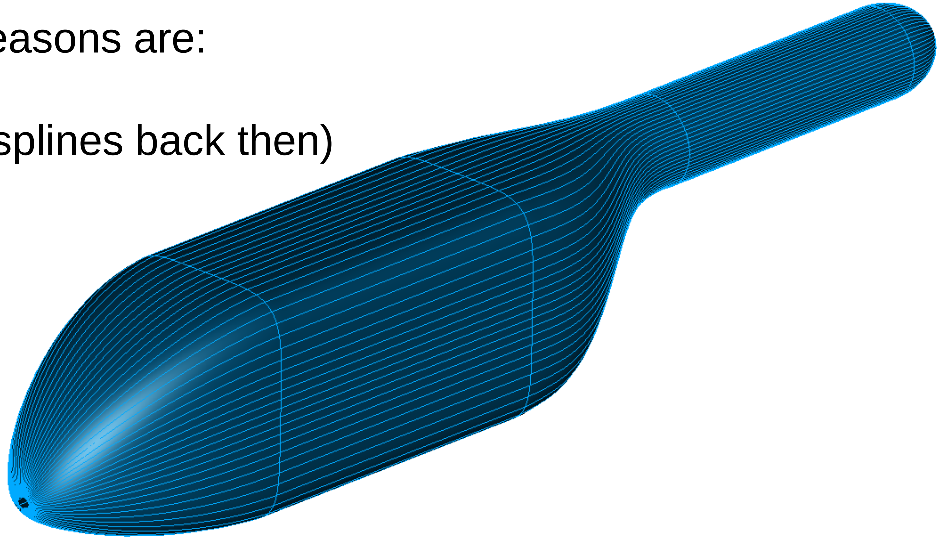
Python API: Geometry

1. TiGL Workshop, September 11 / 12, Cologne

Martin Siggel + Jan Kleinert
German Aerospace Center

Motivation



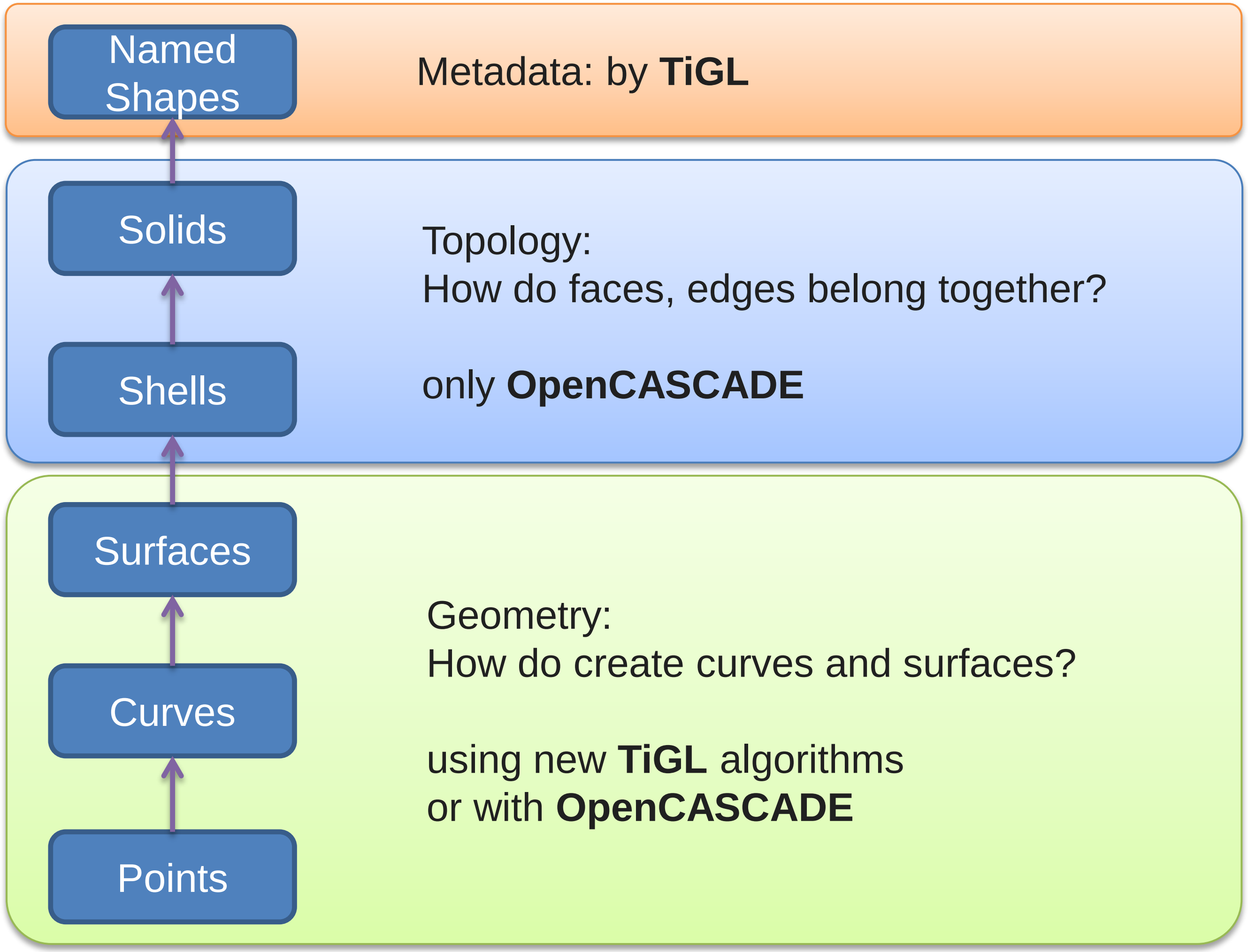
- We had different problems with the surfaces created by OpenCASCADE. Reasons are:
  - We used OpenCASCADE as a black box (we had no background in B-splines back then)
  - The resulting surfaces have sometimes bad quality
  - Not all modelling algorithms available that we needed

➢ We started developing our own algorithms ☺

➢ **Even if you don‘t use CPACS oder TiGL‘s aircraft models, you can now use the algorithms in your own applications**

We show you now how to do it!

Big Picture
The shape creation process



Metadata: by **TiGL**

Topology:
How do faces, edges belong together?

only **OpenCASCADE**

Geometry:
How do create curves and surfaces?

using new **TiGL** algorithms
or with **OpenCASCADE**

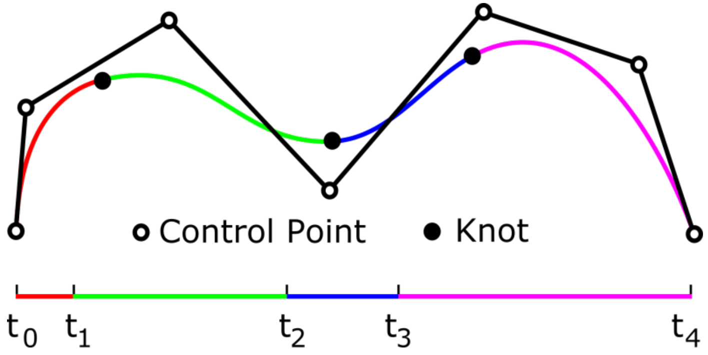
Bezier / B-splines / NURBS
The basis for all geometry reprentations in OpenCASCADE

- B-spline curve:

$$\boldsymbol{c}(u) = \sum_{i=0}^{n} \boldsymbol{P}_i * N_i^d(u, \boldsymbol{t})$$

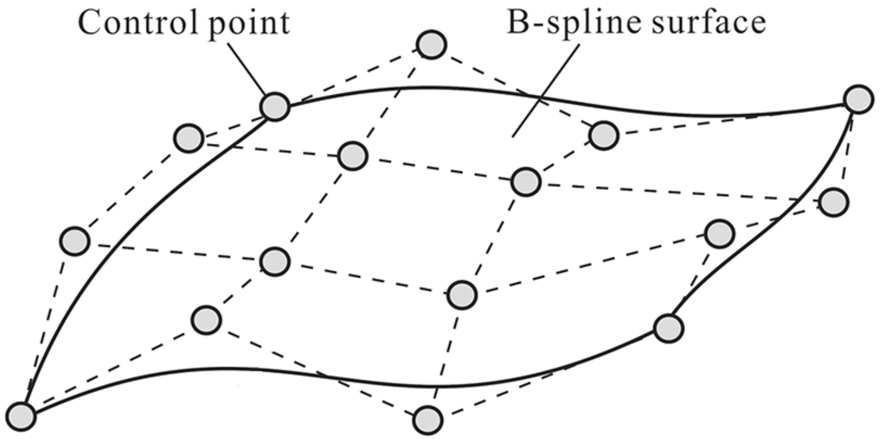
with:

- Control points $\{P_i^c\}$
- B-spline basis functions $N_i^d(u, \boldsymbol{t})$
- Knot vector $\boldsymbol{t}$, $t_i \leq t_{i+1}$



- B-spline surface:

$$\boldsymbol{s}(u,v) = \sum_{i=0}^{n} \sum_{j=0}^{m} \boldsymbol{P}_{ij} * N_i^{d_u}(u, \boldsymbol{t}_u) * N_j^{d_v}(v, \boldsymbol{t}_v)$$



B-spline curve interpolation

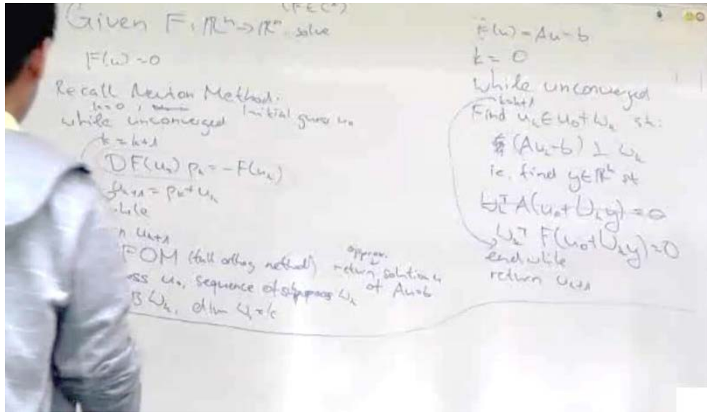
Or: PointsToCurve

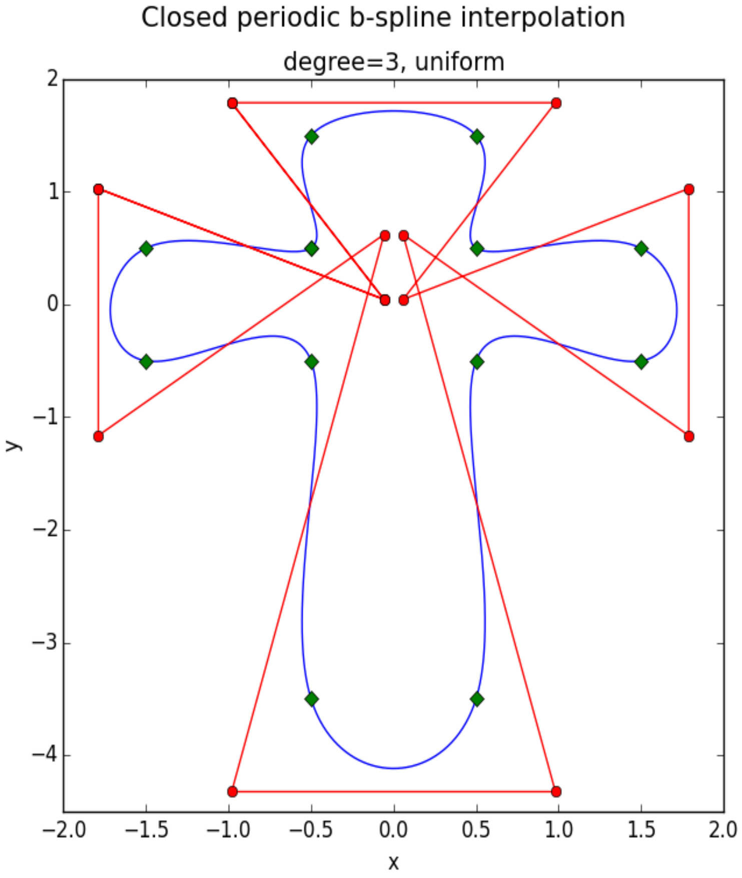
- Solve control points Pi, given data points Dj, such that:

$$\sum_{i=0}^{n} \boldsymbol{P}_i * N_i^d(u_j, \boldsymbol{t}) = D_j$$

$$\Rightarrow \boldsymbol{Np} \equiv \boldsymbol{d}$$

i.e. the curve passes though the data points





Creating curves with TiGL
Curve Factories

- The package **tigl3.curve_factories** provides functions to create B-spline curves

- B-spline Interpolation:

```
import tigl3.curve_factories

# array of 3d points
points = [[0, 0, 0], [1, 0, 0], [1, 3, -1], [0, 0, 0]]

# create the curve
curve = tigl3.curve_factories.interpolate_points(points)
```

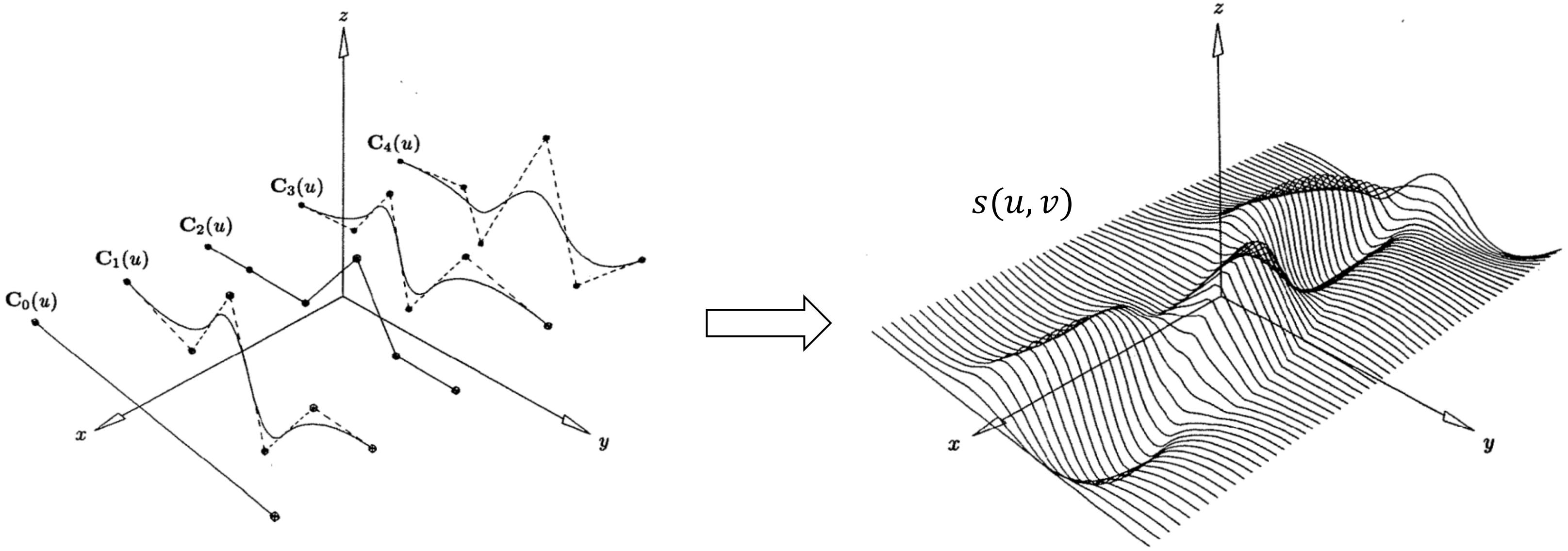
- Even better: control at which curve parameter each point is interpolated!

```
parameters = [0., 0.2, 0.7, 1.0]

# create the curve
curve = tigl3.curve_factories.interpolate_points(points, parameters, degree=2)
```

B-spline surface skinning

Or: CurvesToSurface

- Interpolates set of B-spline curves $c_i(u)$ by B-spline surface $s(u,v)$



- Also involves solving multiple linear systems

Creating surfaces with TiGL
Surface Factories

- The module **tigl3.surface_factories** provides functions to create B-spline surfaces

- Skinning a set of curves:

```
import tigl3.surface_factories

# create the surface
surface = tigl3.surface_factories.interpolate_curves([curve1, curve2, curve3, ... curveN])
```

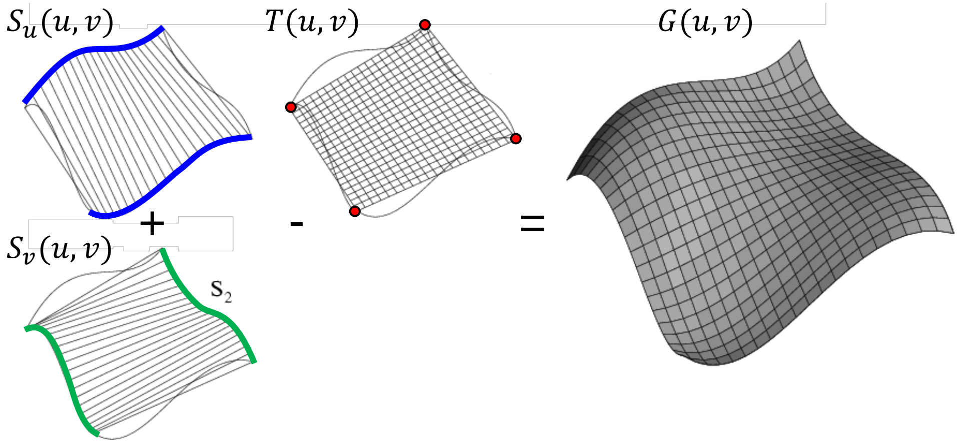
- Similar to curve interpolation – define a set of parameters at which each curve should be interpolated:

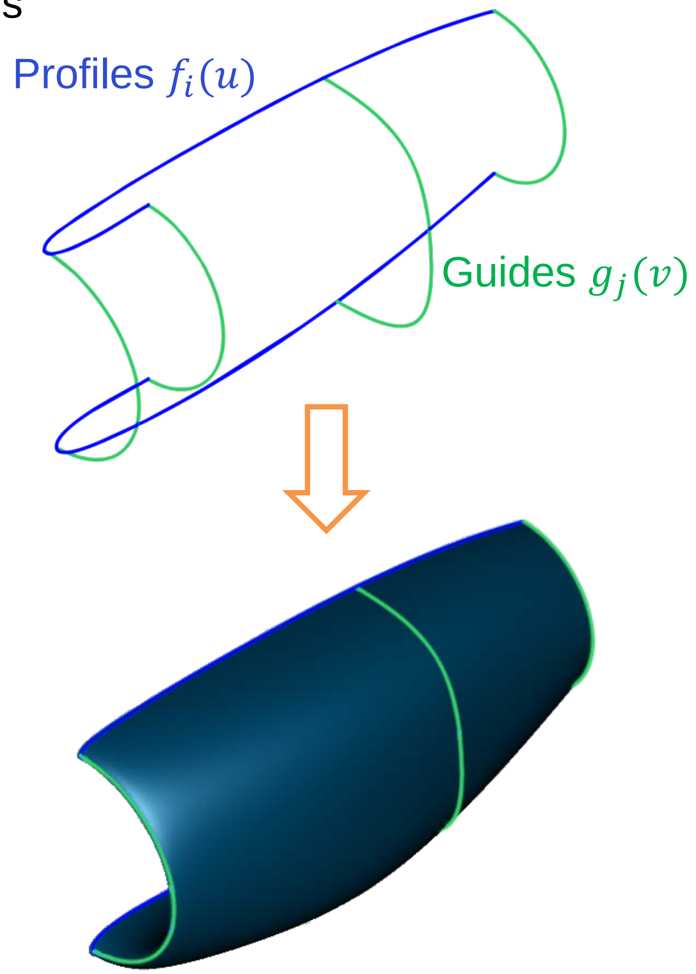
```
parameters = [0., 0.333, 1.0]

# create the surface
surface = tigl3.surface_factories.interpolate_curves([curve1, curve2, curve3], parameters)

# or control the degree. degree=1 is linear lofting. Default degree is 3
surface = tigl3.surface_factories.interpolate_curves([curve1, curve2, curve3], degree=2)
```

Gordon Surfaces

Or: Curve network interpolation

- Given network of profile and guide curves: Find surface that interpolates these curves





$$G(u,v) = S_u(u,v) + S_v(u,v) - T(u,v)$$

Creating surfaces with TiGL

Surface Factories

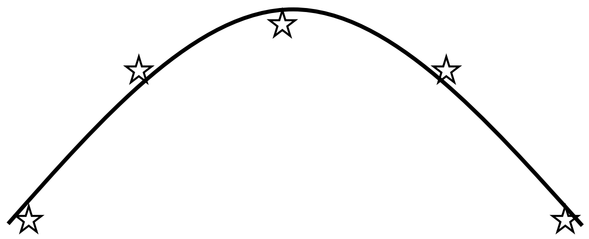
- Interpolating a curve network (using the Merlin‘s Gordon Surface technique):

```
import tigl3.surface_factories

# interpolate the curve network of profiles and guides
surface = tigl3.surface_factories.interpolate_curve_network(
    [profile1, profile2, profile3, ...],
    [guide1, guide2, ...],
    spatialTol=3e-4
)
```

- In theory: Profiles and Guides must all intersect each other exactly!

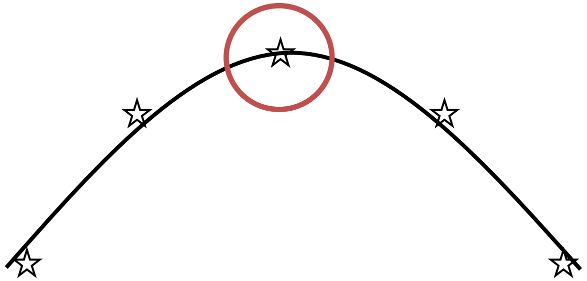
- In TiGL:
  - Parameter spatialTol defines the maximum allowed distance between a guide and a profile
  - If they don‘t intersect exactly, the surface will be somewhere between both curves!

Other Geometry Algorithms in TiGL



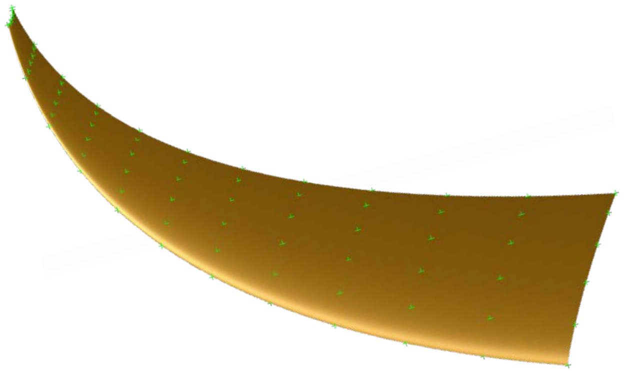
- B-spline approximation: Fit a curve to a set of points
  → `tigl3.geometry.CTiglBSplineFit`

- B-spline representation of arbitrary analytical functions
  (e.g. How does the B-spline representation of CST curves look like?)
  → `tigl3.geometry.CFunctionToBSpline`



- Hybrid B-spline approximation + interpolation of selected points
  → `tigl3.geometry.CTiglBSplineApproxInterp`

- Interpolate a grid of points with a surface
  → `tigl3.geometry.BSplineAlgorithms_points_to_surface`



Remarks on programming with the geometry module

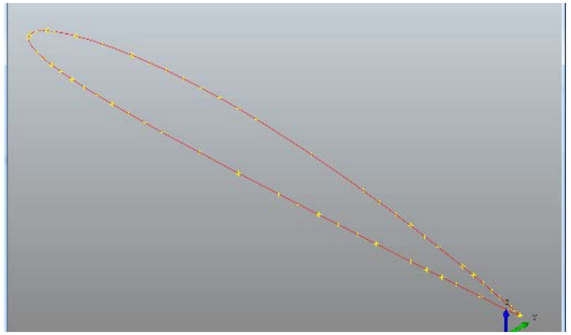
- Geometric objects (curves and surfaces) are returned by a **Handle**
- OpenCASCADE Handles are **Smart Pointers** that automatically free memory, when not needed
- Unfortunately, this is still exposed in Python. We are working on it, to remove this from Python.
- Whenever you e.g. get a `Handle_Geom_BsplineCurve` and you need a `Geom_BsplineCurve`, call its `.GetObject()` method:

```
b_spline = b_spline_handle.GetObject()
```

- Whenever you have e.g. a `Geom_BsplineCurve` and you need its Handle, call its `.GetHandle()` method:

```
b_spline_handle = b_spline.GetHandle()
```

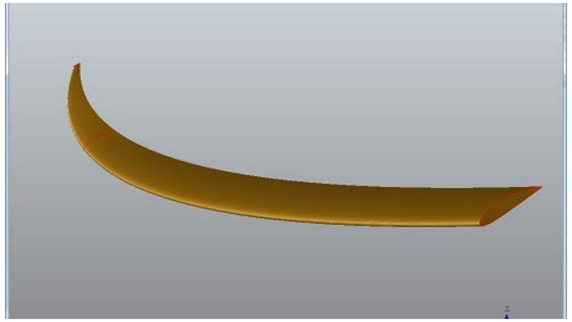
Excercise Geometry:



Goal:

Learn, how to use our geometry tools.

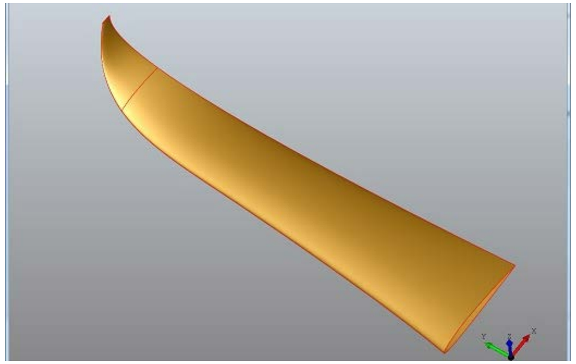
Tasks:



1. Create an airfoil by interpolating a list of points.

2. Use our geometry tools to skin multiple airfoils to create wing loft.

3. Use the curve network interpolation to create a wing loft with a custom leading edge.



Questions?