2nd AIAA Geometry and Mesh Generation Workshop
AIAA SciTech - San Diego, CA
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RBF Morph and ANSYS Contribution to GMGW-2 (case 3 - OPAM-1)

pid: 19

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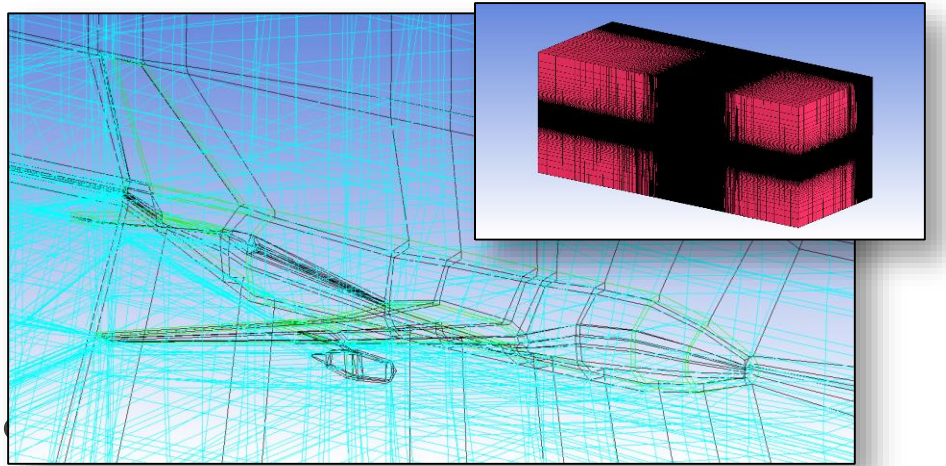
Summary of grids generated

Case	Code	Starting geometry	Generation technique	Grid levels
Case 3a	ICEM CFD	case3a.stp	Structured hexahedral	4
Case 3b	RBF Morph	Baseline mesh	Mesh morphing	4
Case 3c	RBF Morph	Baseline mesh	Mesh morphing	4
Case 3d	RBF Morph	Baseline mesh	Mesh morphing	4
Case 3e	RBF Morph	Baseline mesh	Mesh morphing	4

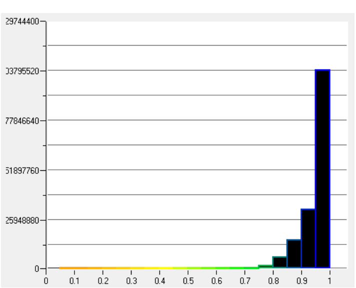
Baseline mesh

- Structured multiblock hexahedral with about **160 million** nodes.
  - O-Grids around all surfaces.
- Half domain extended **100** fuselage length upstream the aircraft, **150** downstream, **50** on the top, **50** on the bottom and **100** on the side.
- Software used:
  - **1 ANSYS CFD PrepPost License:**
    - **SpaceClaim (used here)**
    - **ICEM CFD (used here)**
    - **Also includes others e.g. Fluent Mesh**

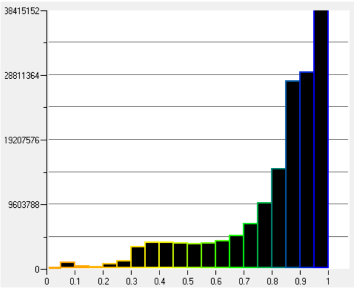


Main quality metrics

- Determinant: Min = 0.0657, max = 1, mean = 0.953
- Orthogonal Quality: Min = 0.0052, max = 1, mean = 0.808

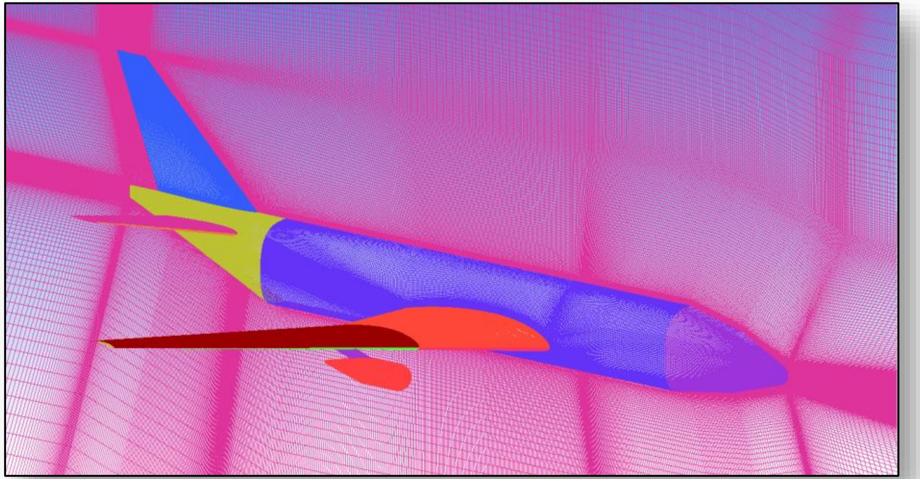


Determinant*



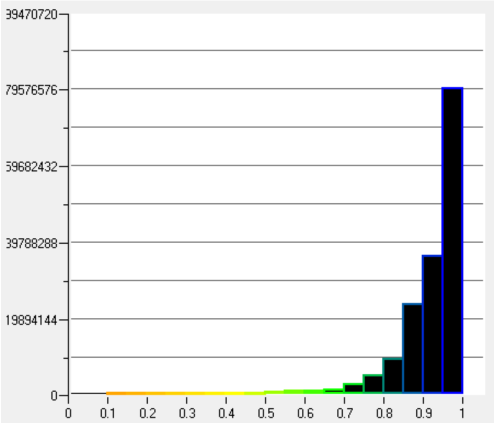
Orthogonal Quality*

*ICEM CFD metrics computation methods



Most critical regions

- Skew: Min = 0.145, max = 1, mean = 0.921
  - 20539 hexa with skew lower than 0.2 (**0.013%** of total)



Skew

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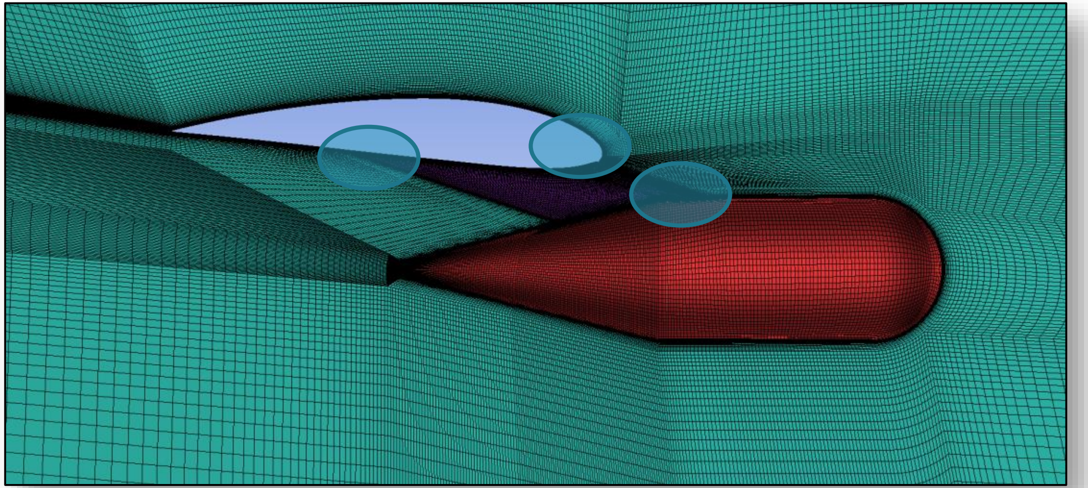
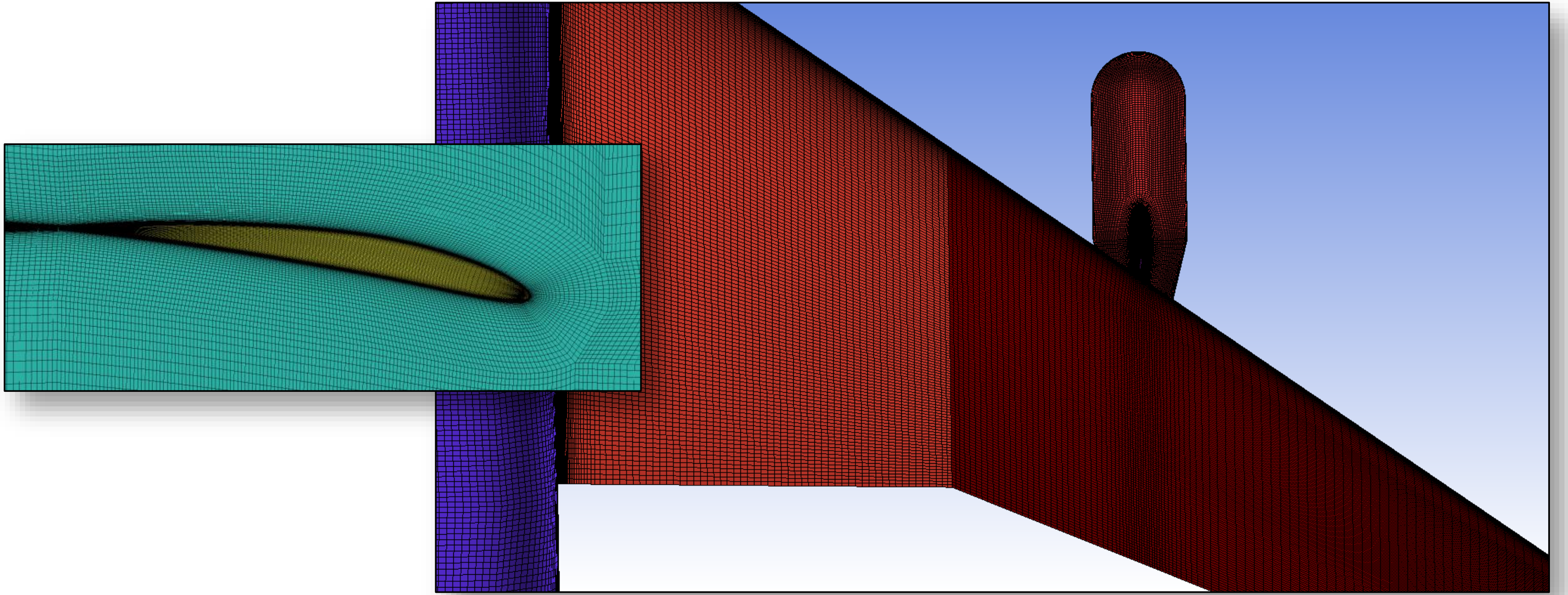
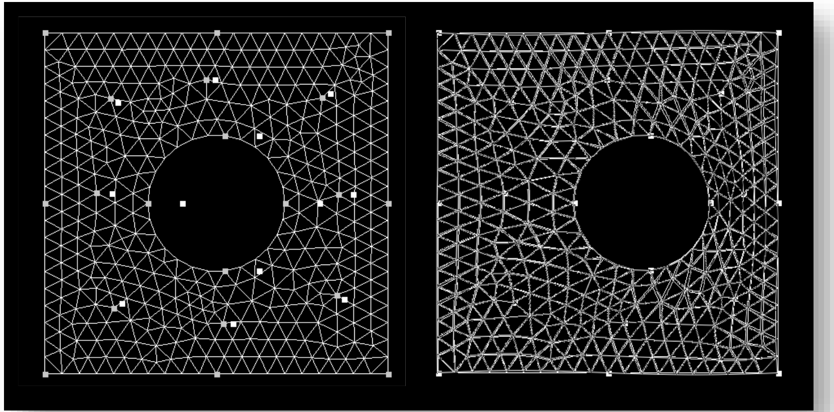


Wing surface and tip

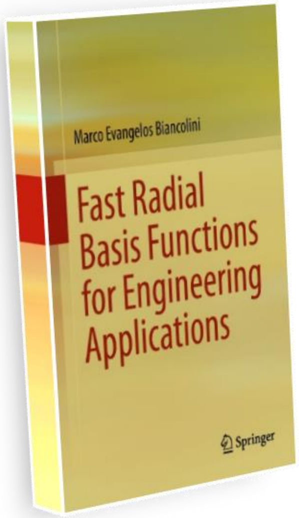


Geometric parameterization

- **Shape parameterization faced by mesh morphing**
- Radial Basis Functions (RBF) are recognized to be one of the best mathematical framework to drive mesh smoothing
- Main advantages:
  - No re-meshing
  - Can handle any kind of mesh
  - Can be integrated in the CFD solver
  - Highly parallelizable
  - Robust process
- Main disadvantages
  - Limitations in the model displacement amplitudes
  - Can not handle topology change
  - Computational costs (HPC for large grids)

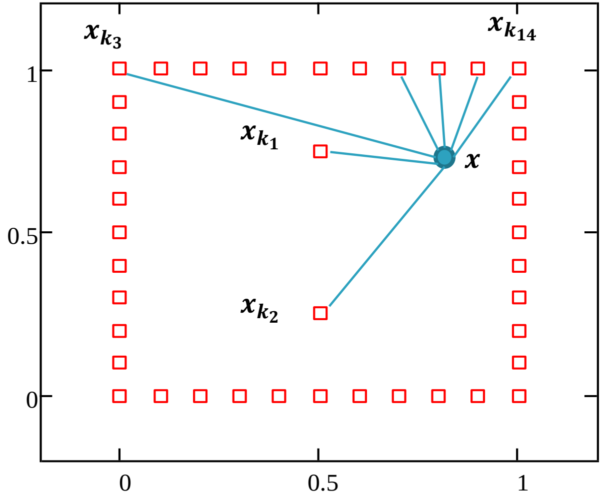


RBF Background



- RBFs are a mathematical tool capable to **interpolate** in a generic point in the space a function **known** in a discrete set of points (**source points**).
- The interpolating function is composed by a **radial basis** and by a **polynomial**.

$$s(\boldsymbol{x}) = \underbrace{\sum_{i=1}^{N} \gamma_i \varphi\left(\left\|\boldsymbol{x} - \boldsymbol{x}_{k_i}\right\|\right)}_{\text{radial basis}} + \underbrace{h(\boldsymbol{x})}_{\text{polynomial}}$$



Biancolini M.E. (2018), *Fast radial basis functions for engineering applications*, Springer. ISBN 978-3-319-75009-5, https://doi.org/10.1007/978-3-319-75011-8.

Welcome to the World of Fast Morphing!

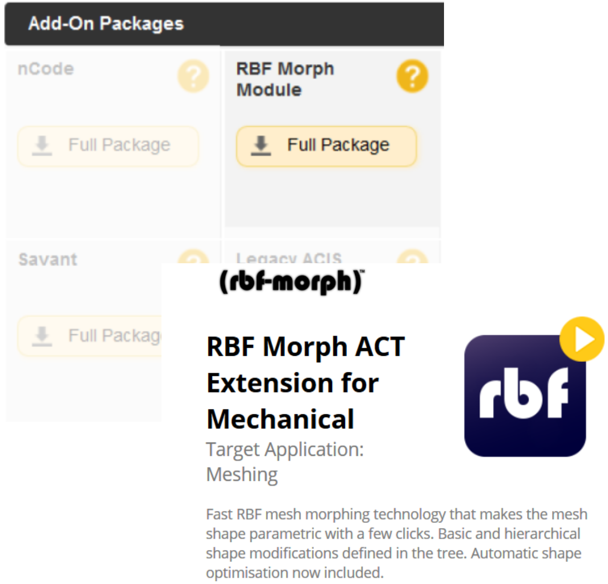
www.rbf-morph.com

GMGW-2, San Diego, CA, January 2019

Two ANSYS-integrated solutions

Fluent Add On

- Released in **2009**
- Fully integrated within Fluent (GUI, TUI & solving stage), Workbench and **Adjoint Solver**
- Multi physics features (**FSI**)



ACT Extension

- Released in **2015**

SACMI

- Fully embedded in ANSYS **Mechanical** (parametric)
- Benefits of **underlying geometry** (or aux geo with dead meshes)
- …**Workbench** Meshing

Consider the brochure of our software.

ANSYS®

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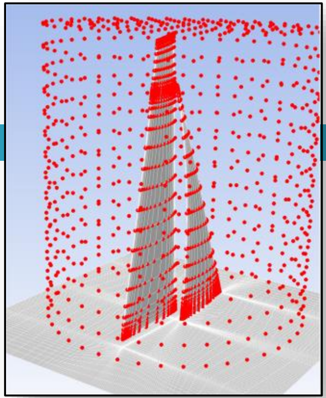
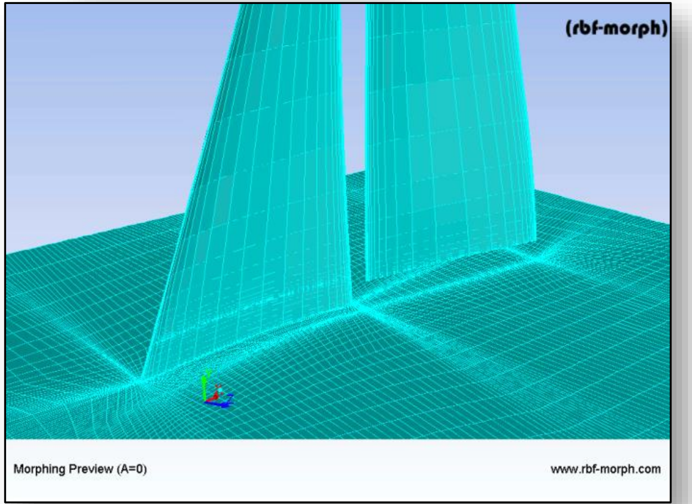
How it works

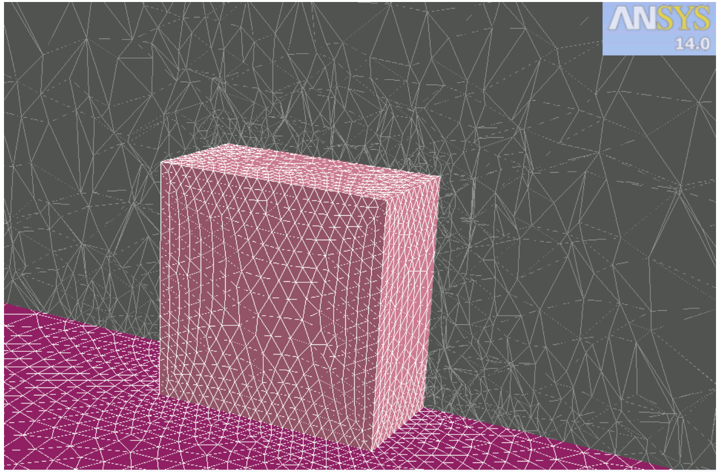


- **Setup**
  - Select fixed and moving walls by source points
  - Prescribe the displacements (or a combination of)
- **Fitting**
  - Solution and storing of the RBF system
- **Smoothing**
  - Application of the computed morphing actions on surfaces and volume



Target STL input

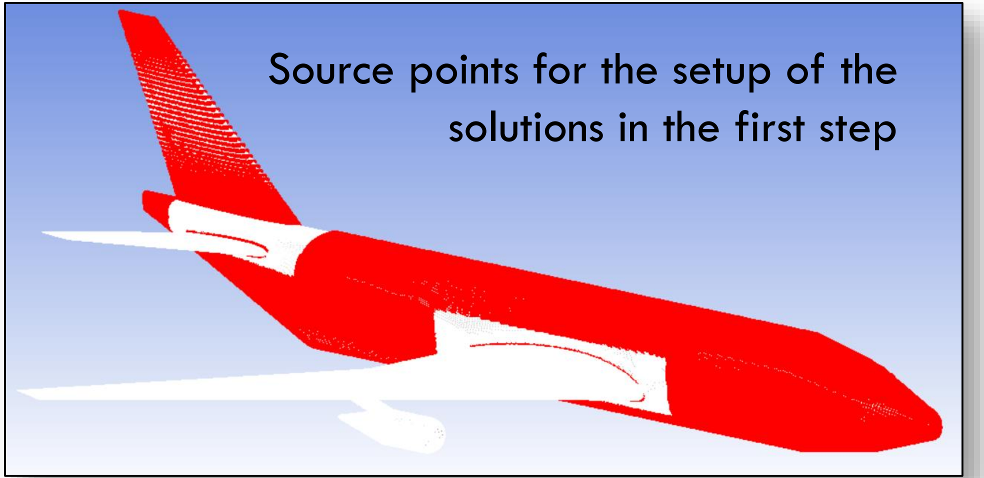
- RBF Morph allows to use external **CAD surfaces** (represented in STL form) as targets for the morphing action.



Surface Grid

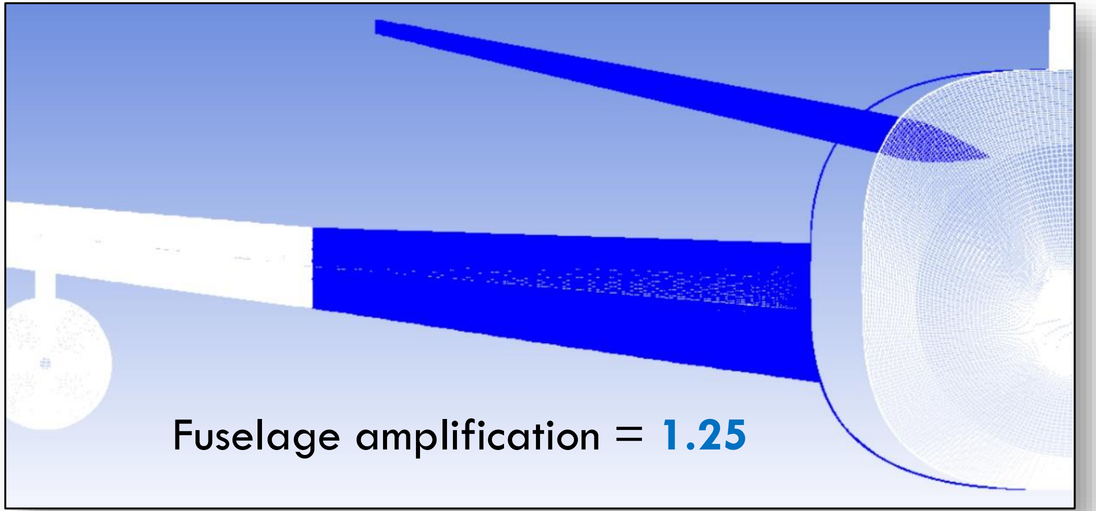
Case 3b - widen fuselage

- Morphing action performed by a so called *two-step* procedure - It consists in prescribing, to selected boundaries, the displacement stored in external RBF solutions.
- First step
  - Compute and store an RBF solution to scale in Y direction the nodes of the fuselage. Vertical Tail is Fixed.
  - Compute and store RBF solutions for the displacement of root sections (wing and horizontal tail).
- Second step
  - Smoothing the whole mesh amplifying the two stored solutions



Case 3b - wing shape recover

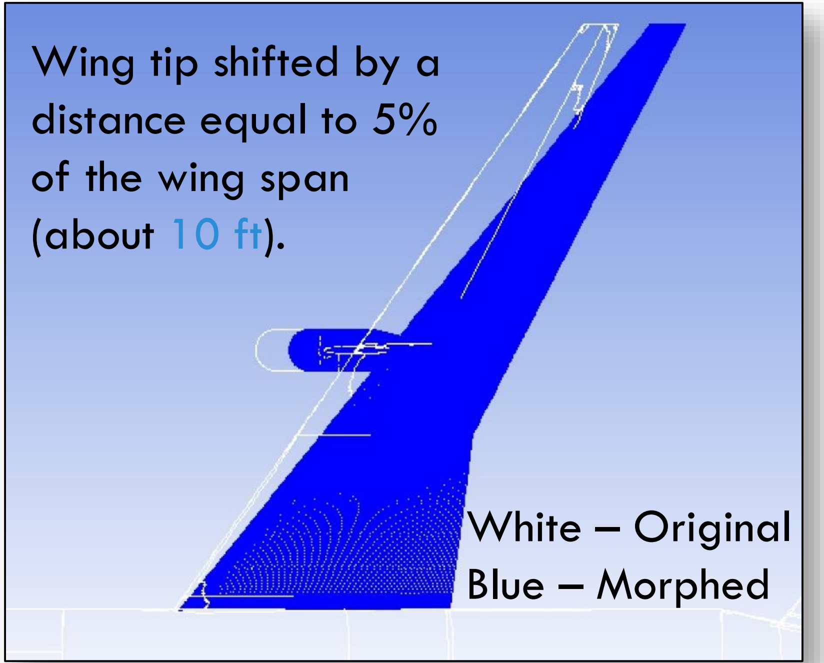
- A second RBF morphing action recover the wing and horizontal surfaces according to the original CAD shape by the STL target feature previously described.



White – Original
Blue – Morphed

Case 3c - wing sweep

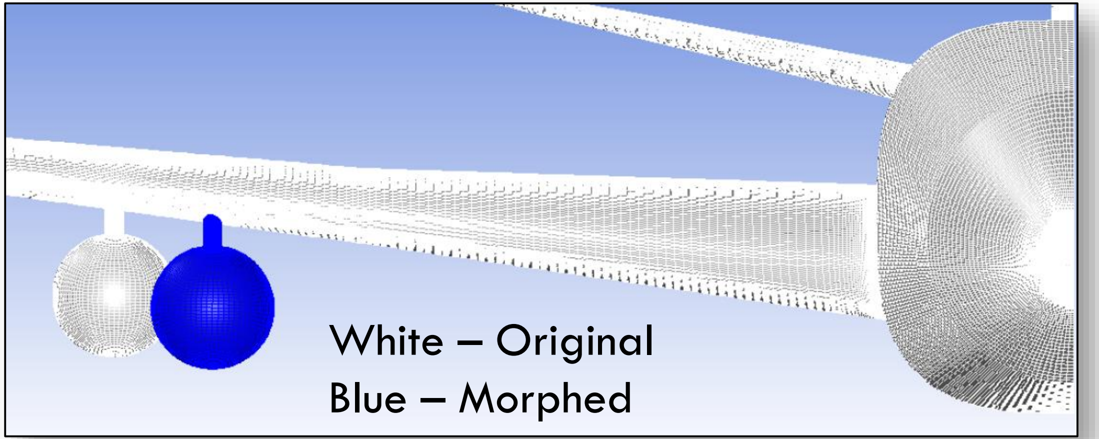
- Morphing action by a *two-step* procedure
- First step
  - Compute and store an RBF solution for the displacement in streamwise direction of a set of wing sections.
- Second step
  - Smoothing the whole mesh applying the stored RBF solution to the wing and rigidly shift the pod.



Case 3d - move pylon

- Two morphing actions applied in sequence:
- First RBF solution
  - Displacement of the group pod/pylon.
- Second RBF solution
  - Recovering of the wing shape by the STL target technique.

Shifting of the pod in the inner direction by 5 ft



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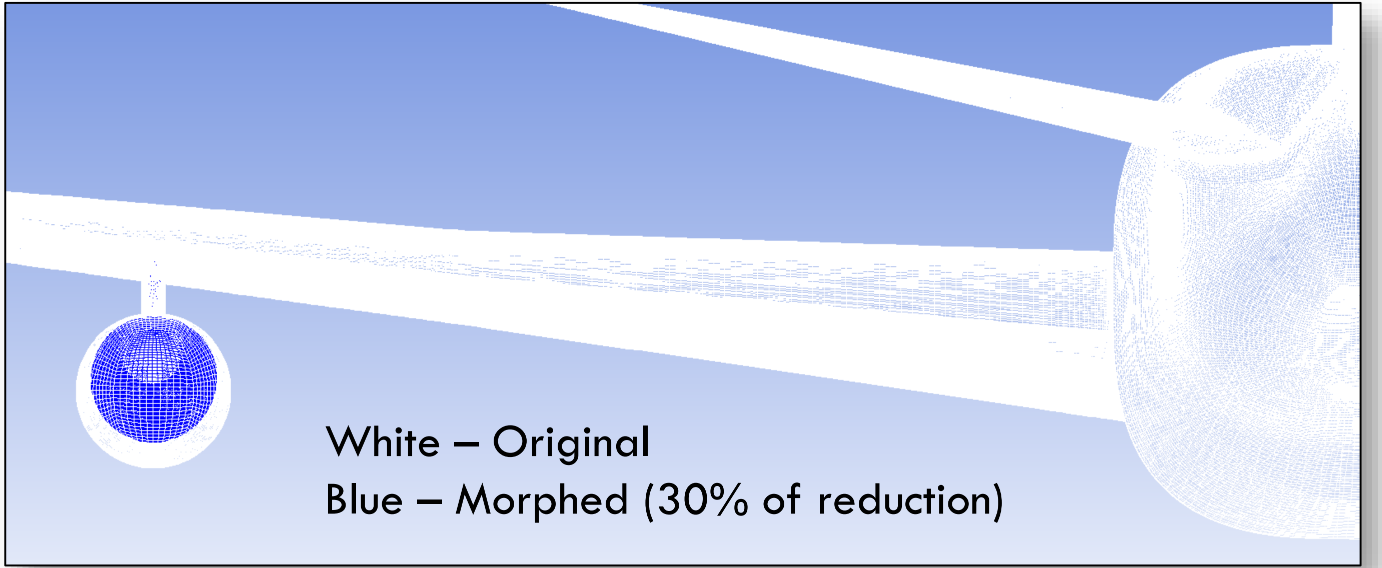
Case 3e - narrow pod

- Simple scaling factor applied to the mesh nodes on the pod surface.



ANSYS

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Resources

Case 3a - baseline mesh
Pre-mesh computation in 20 seconds (serial mode)
Conversion and saving (ICEM format) in 100 seconds (serial mode)
Exporting in Fluent format in 4.5 minutes (serial mode)
50 GB RAM required
Case 3b - widen fuselage
Mesh Morphing performed in 405 + 235 = 640 seconds (84 cores, 200 GB RAM)
Case 3c - wing sweep
Mesh Morphing performed in 570 seconds (84 cores, 200 GB RAM)
Case 3d - move pylon
Mesh Morphing performed in 103 + 75 = 178 seconds (84 cores, 200 GB RAM)
Case 3e - narrow pod
Mesh Morphing performed in 50 seconds (84 cores, 200 GB RAM)

Conclusions

- The adoption of RBF morph allowed to replicate the four parametrizations required and to benefit of the **advantages** offered by the RBF mesh morphing approach:
  - no re-meshing required;
  - "meshless" nature of the method (works with any kind of domain);
  - integration in the solving process (morphing action can be performed "on the fly" during the computation);
  - highly parallelizable;
  - robustness.
- The main weaknesses are related to the **limitations in the space of variables** and to the **incompatibility with topological modifications**.
- The time required for morphing can be **comparable** with the time required for the generation of a structured mesh and, in general, **lower** that the time required to regenerate an unstructured mesh.

goo.gl/1svYd

twitter.com/RBFMorph

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rbf-morph.com

Many thanks for your kind attention!

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