Automatic shape optimisation using the Biological Growth Method (BGM) with RBF Morph ACT Extension and ANSYS Mechanical
Outline

- RBF Morph UTV synergy
- Parametric CAE
- Software line
  - RBF Morph Fluent Add On
  - RBF Morph ACT Extension
- BGM sculpting
  - BGM Background
  - RBF Background
  - Examples
- Conclusions

RBF Morph - www.rbf-morph.com
A powerful synergy

- A variety of applications ranging from research to industrial exploitation can be tackled
- Technology transfer is boosted (including personnel)
- Funds access is facilitated
- A network of partners (Industries, Universities, Research Institutes, CAE Companies)

UTV + ISV RBF Morph

Academic

CAE business

(www.rbf-morph.com)
Geometry - CAE link

RBF mesh Morphing

- Main advantages
  - No re-meshing
  - Can handle any kind of mesh
  - Can be integrated in the CAE solver
  - Highly parallelizable
  - Robust process

- Main disadvantages
  - Can’t handle topology change
  - Back to CAD procedure required

CAD to mesh

- Main advantages
  - Accurate geometry quality control
  - High constraints setup flexibility
  - No “back to CAD” required

- Main disadvantages
  - Complex setup
  - Highly skilled CAD user required
  - Robustness
  - Remesh required

RBF Morph - www.rbf-morph.com
Parametric CAE models

RBF Morph makes the CAE model **parametric** with respect to the **shape**.

Works for **any size of the mesh**.

Shape parameters can be steered with the **optimizer of choice**.

RBF Morph - www.rbf-morph.com
<table>
<thead>
<tr>
<th>Fluent Add On</th>
<th>Stand Alone</th>
<th>ACT Extension</th>
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<tbody>
<tr>
<td>• Released in <strong>2009</strong></td>
<td>• Released in <strong>2012</strong></td>
<td>• Released in <strong>2015</strong></td>
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<tr>
<td>• Fully integrated within Fluent (GUI, TUI &amp; solving stage), Workbench and <strong>Adjoint Solver</strong></td>
<td>• Tcl/Tk GUI accepts <strong>CGNS</strong> and <strong>STL</strong> (Linux only)</td>
<td>• Fully embedded in <strong>ANSYS Mechanical</strong> (parametric)</td>
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<tr>
<td>• Multi physics features (<strong>FSI</strong>)</td>
<td>• <strong>Cross solver</strong> (OpenFoam, CFD++, SU2, Fluent, Nastran, ANSYS, Abaqus)</td>
<td>• Benefits of <strong>underlying geometry</strong> (or aux geo with dead meshes)</td>
</tr>
<tr>
<td></td>
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<td>• <strong>…WB Meshing</strong></td>
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RBF Morph ACT Extension

Released in 2015. Available also on the ANSYS App Store.

https://youtu.be/TUOJGAG7Wtk
RBF Morph - www.rbf-morph.com
Two parameters allow to get a 22.5% stress reduction.
ACT Extension for Mechanical

- Deeply integrated in ANSYS Mechanical: same look & feel, same interaction logic, same parameters!
- Nested in the usual Mechanical tree as an added object, shares its scoping tools for geometrical and mesh elements selections
- Written in python and xml, uses external RBF library (OpenMP and CUDA powered)
- Child hierarchical logic for complex morphing (two steps, three steps, ..., n steps setups)

RBF Morph - www.rbf-morph.com
BGM SCULPTING APPROACH

ACT Extension based workflow
The circular shape is transformed onto a rectangular filleted one

Stress reduction at a circular hole

https://youtu.be/HShUgsK4Avk

RBF Morph - www.rbf-morph.com
BGM Background

- **Biological** structures growth is driven by local level of stress
- Bones and trees’ trunks are able to **adapt the shape** to mitigate the stress level due to applied loads
- The process is driven at surface. Material can be removed or added according to the **stress** level
- Introduced by Mattheck in 1990

Reduction of maximum stresses 56%
The idea of BGM is that the local growth can be expressed by a linear law provided a given threshold

$$\dot{\varepsilon}_v = k (\sigma_{Mises} - \sigma_{ref})$$

The concept has been refined by Waldman proposing a multi peaks approach

$$d_i^j = \left(\frac{\sigma_i^j - \sigma_{th}^j}{\sigma_{th}^j}\right) s \cdot c, \sigma_{th}^j = \max(\sigma_i^j) \text{ if } \sigma_i^j > 0 \text{ or } \sigma_{th}^j = \min(\sigma_i^j) \text{ if } \sigma_i^j < 0$$

Updating of the structural mesh is a challenge that can be tackled by advanced RBF mesh morphing
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**.

\[ s(x) = \sum_{i=1}^{N} \gamma_i \varphi \left( \| x - x_{k_i} \| \right) + h(x) \]
The offset operator of RBF Morph can be driven by the **Driven Value** option.

Many set of surfaces can be controlled with set wise rules for BGM **Threshold** and **intensity** (i.e. max Offset).

The “**BGM mode**” allows to suppress automatic Generate and morphing happens after solution.

DPs are populated with the BGM growth **sequence**.
Examples: cantilever beam
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Examples: cantilever beam
Examples: cantilever beam

- Stress sculpted
- Parabolic shape and uniform stress
- 33% mass reduction
Examples: turbine blade

- □ 10% stress reduction
WHAT MORE?

ACT Extension based workflows
Morphing using geometrical targets

Squaring of the circle? Sphering of the Cube!

RBF Morph - www.rbf-morph.com
Parametric clew

Clew location controlled by DesignModeler

Clew depth controlled by RBF Morph
Connecting rod optimization

- Original design: 358.7g
- Optimal design: 334.4g

- Four parameters allow to get a 7% mass reduction
Ductile iron castings

https://doi.org/10.1007/s00158-018-1929-z
CAD driven mesh morphing

RBF Morph - www.rbf-morph.com
Fracture propagation (RBF4CRACKS)
Conclusions

- RBF Morph is an advanced mesh morphing technology based on Radial Basis Functions
- A shape parametric mesh is obtained. Parameters can be steered using standard optimization tools. On the fly computed shape evolution can be pursued as well!
- Strong integration in ANSYS products: an Add On for Fluent & ACT Extension for Mechanical (and more…)
- BGM capabilities of RBF Morph ACT Extension are today demonstrated
- Many advanced industrial applications can be faced. Visit our web site www.rbf-morph.com to learn more.
Many thanks for your kind attention!