Next Generation Morphing in in MSC.SOFY

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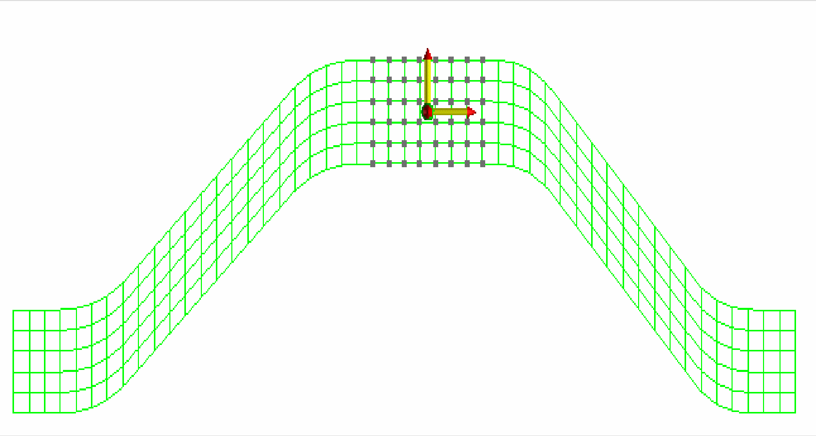
Abstract

In 2001, Ford Motor Company began to regularly use finite element mesh morphing to support concept design studies. Since that time, morphing technology has generally remained unchanged. Although there have been improvements in usability and ergonomics over the years, these improvements haven't significantly improved capabilities. Current morphing technology still struggles with poor element quality, lack of feature control, and significant upfront time investments. This document proposes several new technology advances that have been prototyped in MSC.SOFY. It is believed that these advances will significantly improve morphing capabilities and expand it's applicability to the concept modeling stages of product development.

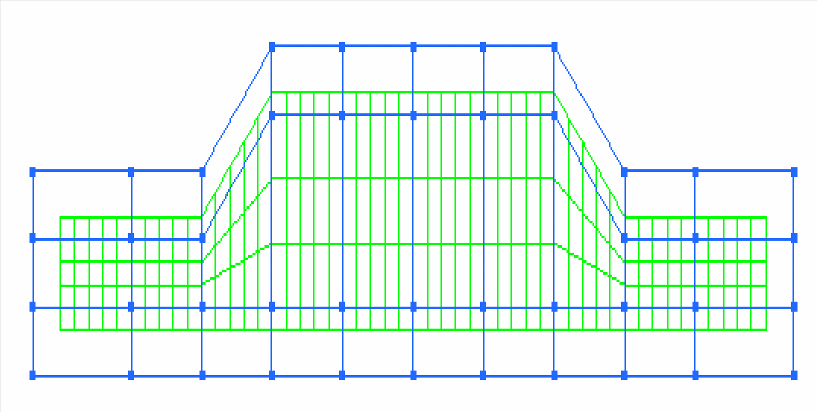
Introduction

1. Current State of Morphing
2. MSC.SOFY Software Prototype: Associative Morphing
3. Next Generation Technologies
4. Example Scenarios
5. Challenges
6. Next Steps

Current State Technology – Shape and Domain Morphing



Shape Morphing – Single/multiple control nodes and deformable nodes. Morph by rigid body deformation of controls.



Domain Morphing –Solid Domains (e.g. boxes) cover deformable nodes. Morph by deforming domains.

Current Morphing Challenges & Issues

1. Limited control. Only a few dimensions / feature can be controlled. Controlling section dimensions is very difficult to do.
2. Significant upfront time investment. Usually done to offset the limited control. Highly complex domain templates have been created with some success.
3. Mesh Quality. Minor issue when stretching. Significant issue when compressing. Most fixes require a very time consuming element-by-element fix. No systematic way to fix.

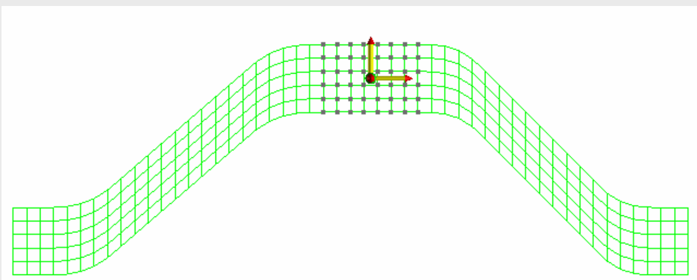
New Engine – Associative Morphing Prototyped Using RADE

Associative Morphing has been prototyped at Ford using Rapid Application Development Environment (RADE: MSC.SOFY interpreter language) and has been used on several concept modeling projects.

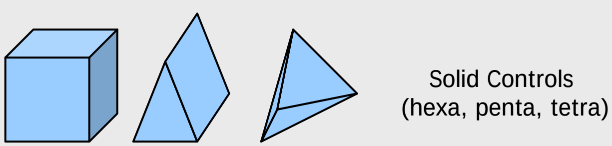
- Single engine unifies Shape and Domain morphing. One GUI/Tool to learn & use.
- Generalizing the control to include points, curves, surfaces, and solids.
- Improved control influence
- Stronger blending control by using sticky zones.
- Morphing with rigid bodies (real time)
- Linking morphs together
- Integrating linear and advanced constraints
- Fixing mesh quality by reverse engineering

Generalization of the Control

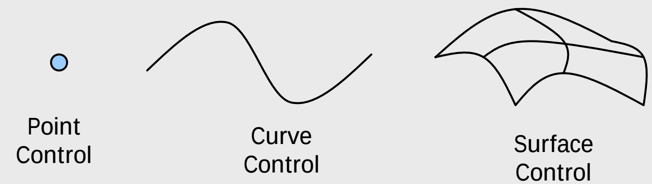
There two aspects to a control. Dimensionality and whether it’s part of the structure or not.

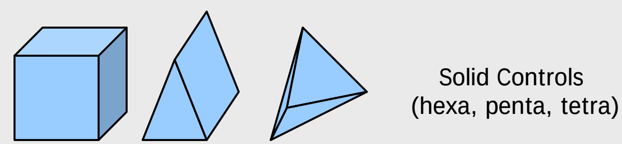


Shape Morphing – node control using the structure. The control may only move in rigid body.



Domain Morphing – solid control using a extra support. The control itself may move rigid body and/or deform.



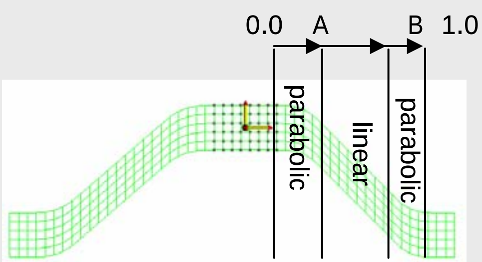


Associative Morphing – support points, curves, surfaces, and solids as controls. Associative uses polylines and meshes for curves and surfaces. Any control may move rigid body and/or deform. It is discovered that the surface control is used most.

These controls may be the existing structure or an added support

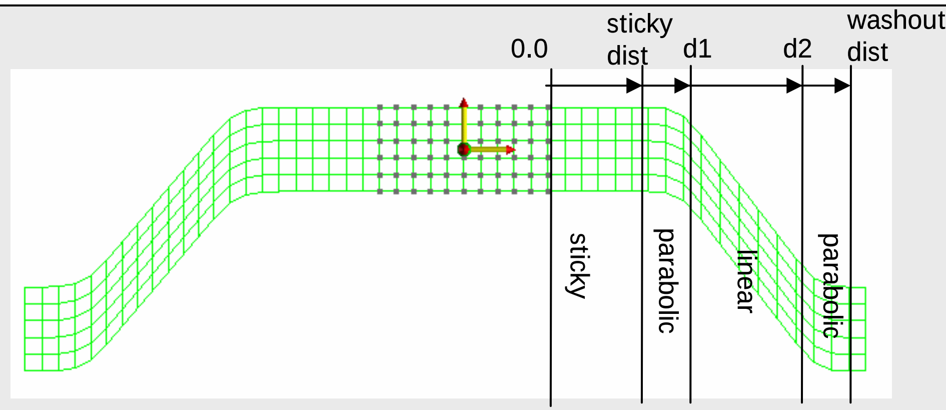
Expansion of the Blending Curves to include Sticky Zones.

Blending logic is used to drive the deformable nodes that are under the influence of multiples controls. Ground should be considered a control.



Shape Morphing – blending is controlled by two normalized parameters (A and B).

Domain Morphing – Blending applicable since each node is driven\ by a single domain.

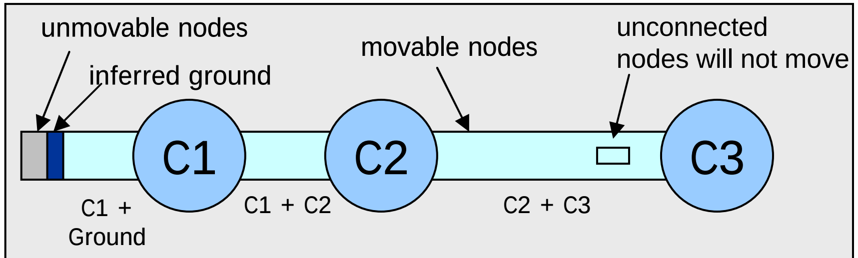


Associative Morphing – Each control is given it's own blending parameters. Instead of using normalized parameters A and B, Associative morphing uses actual distances. The sticky zone is the area which will track rigidly with the control. In many cases, when multiple controls are used, the washout distance is infinity (i.e. the controls act a ground).

Note: Adding more blend shape control was considered, but it is felt it is not needed. If the shape of the blended region is important, more controls should be create (i.e. don't over-use blending to get a desired shape).

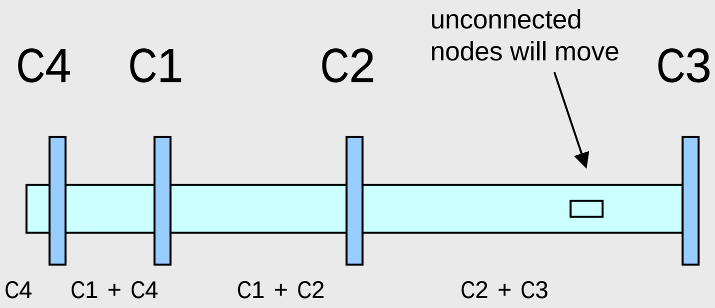
Improved Influence and Ground Control

Need a robust algorithm to determining which controls will influence a particular node. Only applicable when more than one control is active.



Shape Morphing – Influence is determined by <u>connectivity</u>. The ground is inferred by determining the interface between movable nodes and the rest of the structure.

Domain Morphing – Neither influence and ground concept are applicable since controls only influence those nodes within a domain.



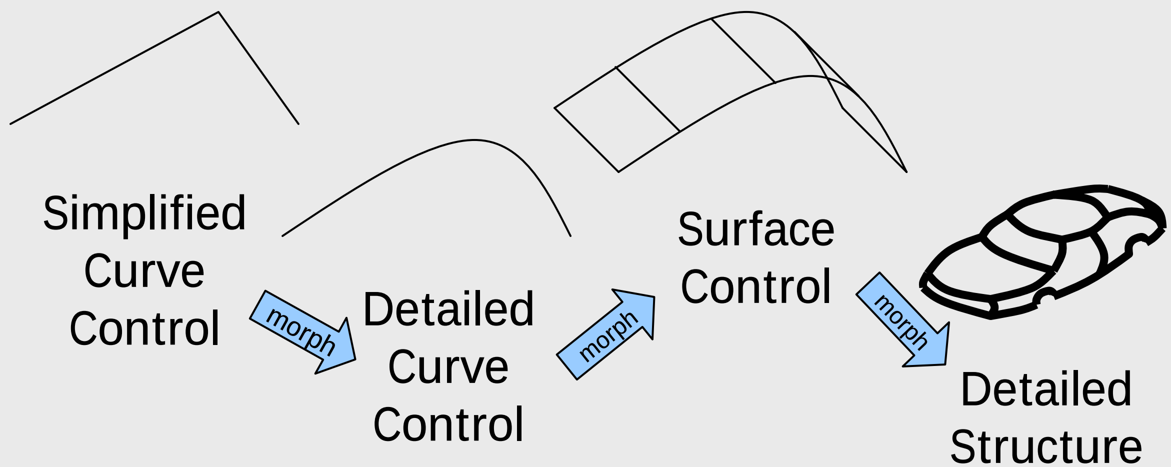
Associative Morphing – apply a <u>“line of sight”</u> influence algorithm. Exclude the influence of those controls which are not seen from a particular deformable node. Only surface and solid controls can block influence. The ground is no longer automatically created (as in shape morphing). This is why C4 is required, but not needed in shape morphing.

Linking Multiple Morphs

Linking morphs is an entirely new concept that both Shape and Domain do not support.

Shape Morphing – No capability to link morphs. Linking morphs will replace the relatively complex Blending Field mechanism.

Domain Morphing – No capability to link morphs.



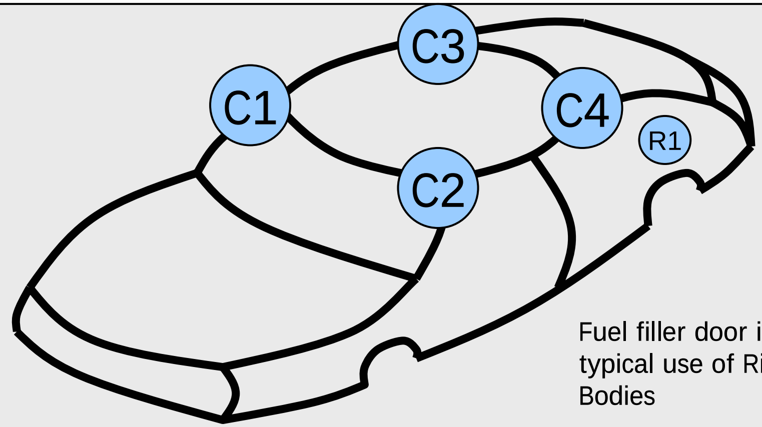
Associative Morphing – Linking morphs will provide the capability to use very simple controls that drive complex structural changes. If simple control do not have enough fidelity, user will start work with the next level of detail. For example, the simplified curve may not support a desired change. The user would then manipulate the detailed curve directly.

Morphing with Rigid Bodies (Real-time)

Need ability to identify features as rigid body. Morphing should automatically move these features. Examples include, holes, carry-over parts, etc.

Shape Morphing – Rigid bodies are created as normal control. “Float” the control into position. Not real-time. Does not support many rigid bodies.

Domain Morphing – Limited capability. Rigid area must be covered by a domain and manually repositioned.



Fuel filler door is a typical use of Rigid Bodies

Associative Morphing – Rigid bodies (e.g. R1) are identified during morph setup. Real-time positioning. Many rigid bodies are supported.

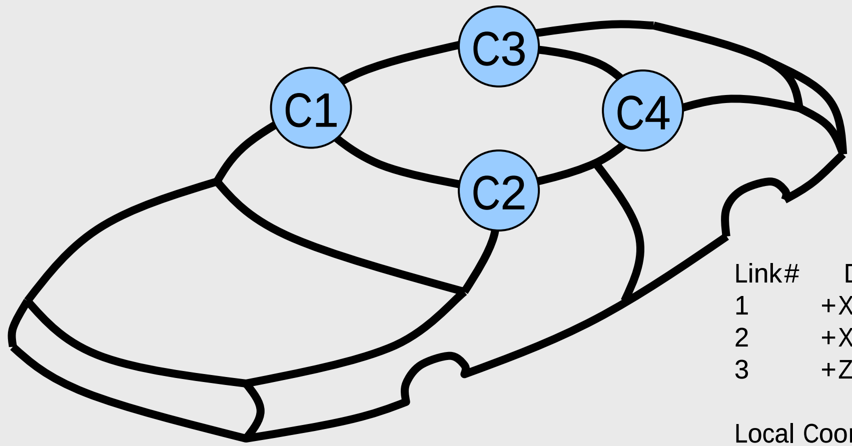
Note: rigid bodies were implemented internally by creating a two step linked morph. R1 control is dependent on C1-C4.

Integrating Linear Constraints

The concept of constraints (linking controls together) needs to be build into the core of the morphing engine.

Shape Morphing – only a symmetry constraint is supported.

Domain Morphing – Constraints not supported.



Link#	DOF	Controls
1	+X,-Y	C1, C2
2	+X,-Y	C3, C4
3	+Z	C1,C2,C3,C4

Local Coordinates are supported.

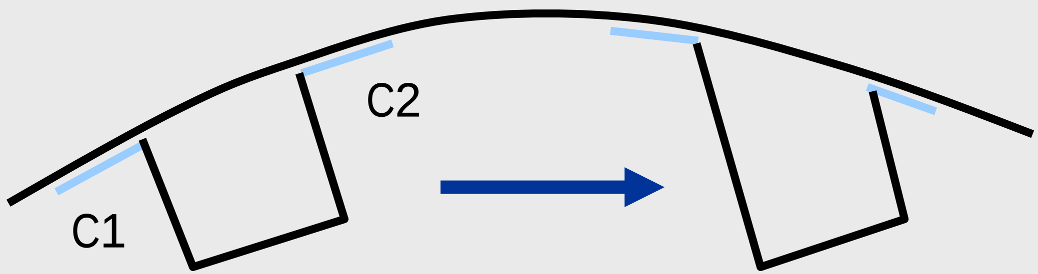
Associative Morphing – Any control may be linked to another control. The linking is displacement-based. This is straightforward with point controls, but will be more complicated on higher dimensional controls.

Integrating Advanced Constraints

The need for advanced constraints should be expected. A general treatment of constraints should support the addition of new types of constraints. For example, a sliding control.

Shape Morphing – only a symmetry constraint is supported.

Domain Morphing – Constraints not supported.

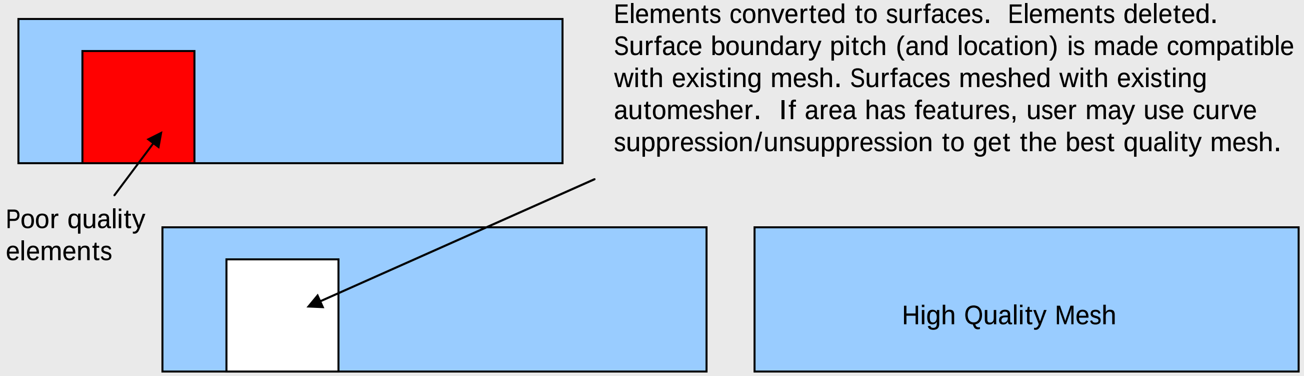


Associative Morphing – the first advanced control that was implemented is the sliding. As the control C1 & C2 are moved to the left or right, it will track a surface (or mesh surface), while maintaining the original gap. This effectively allows users to “slide” cross-members to a new location. Note: connections will also be morphed, facilitating a post-morph re-welding step.

Fixing Mesh Quality by Reverse Engineering

Assuring acceptable mesh quality is key to a successful morphing project.

Current Process – automatic element smoothing. If significant quality problems, only element-by-element works. Automatic element splitting and merging is not robust.



Associative Morphing – No direct support of Mesh Quality. It is believed that Morphing should focus solely on getting the desired shape. Identifying & Fixing any mesh quality problems is best done after morphing (i.e. after the desired shape has been achieved).

Reverse Engineering is the process of converting elements to surfaces. Once the surfaces are created the user automeshes the area with high quality elements. This functionality (elems to surfs) has been prototyped at Ford.

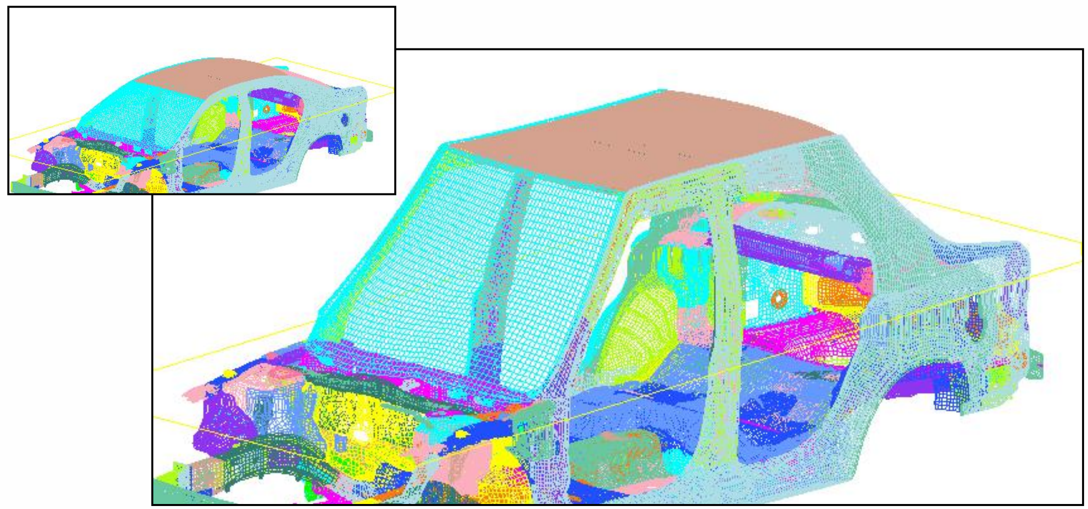
Example Scenarios

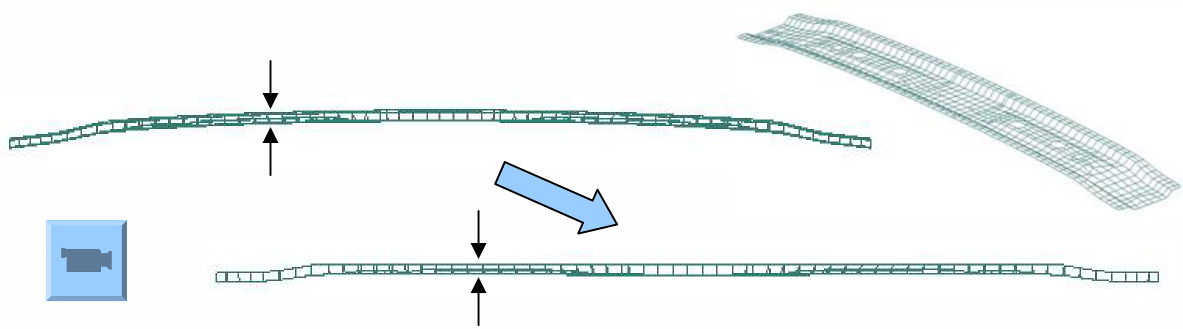
- Modifying roof shape while maintaining roof bow section
- Using center line curve to support a door opening change.
- Morphing an A-Pillar section
- Fixing a mesh using reverse engineering
- Structured Morphing – blending parametric and morphing together.

Modifying roof shape while maintaining roof bow section

While moving and reshaping the roof, the roof bow section is maintained to keep the exact same section depth.

Only two controls were used: one surface control for the roof, and another surface control for the ground (yellow plane). The second control was oversized in order to block the roof's influence below the belt-line. The roof control was given a sticky distance greater than the depth of the roof bow section.





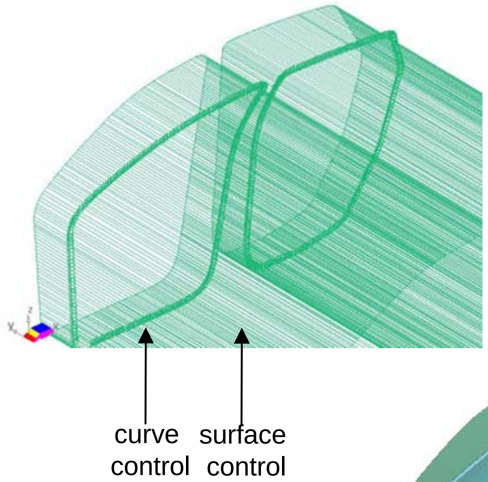
** you may notice some nodes getting pulled below the yellow control. This is bug in the influence blocking algorithm.

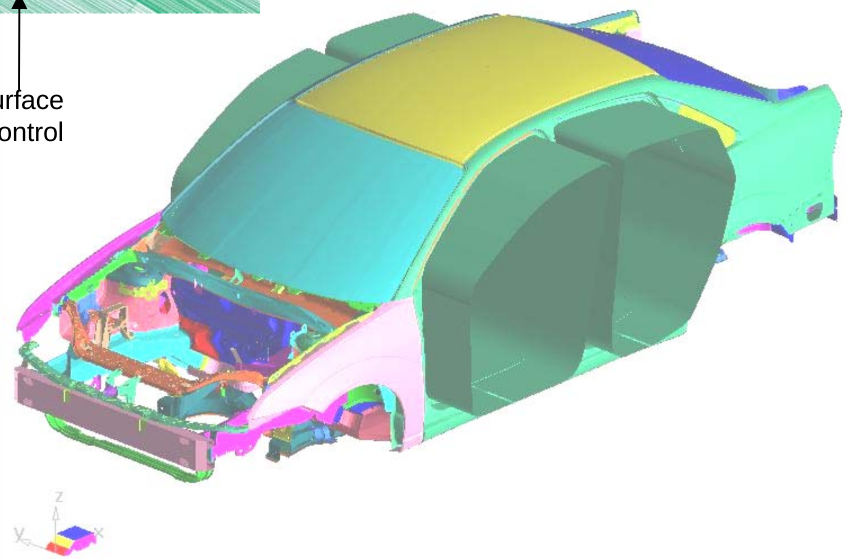
Using center line curve to support a door opening change.

A linked morph was used to manage the relationship between the curve control to the surface control to the detailed structure.

By moving/projecting the curve control, the surface is updated. The structure will then be updated accordingly.

Extra constraints were added such that curve control deformation in the Y direction does not affect the surface control. This supports projecting the curve control to any door open section (e.g. at y=0, center line).

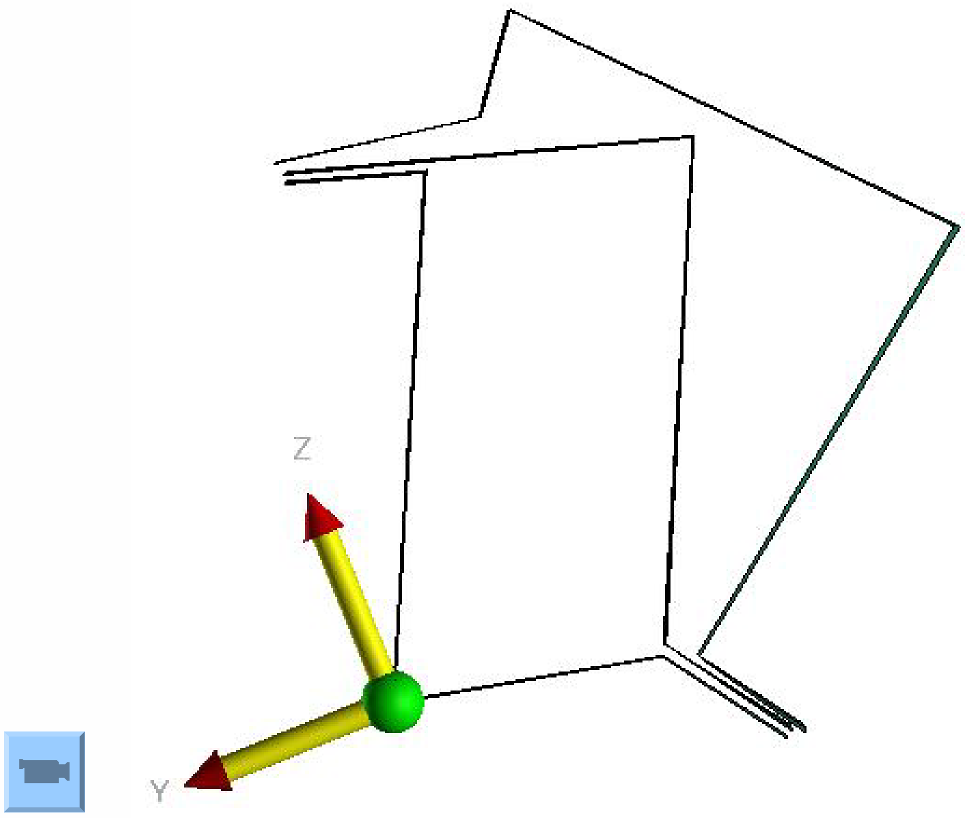




Morphing an A-Pillar section

Morphing a section is supported by creating a beam support – a surface control. An extra tool was created to expedite this step. Along with creating the control, advance constraint were added. The constraint allow the user to modify any section of the beam support. The changes are automatically propagated along the length of the beam control.

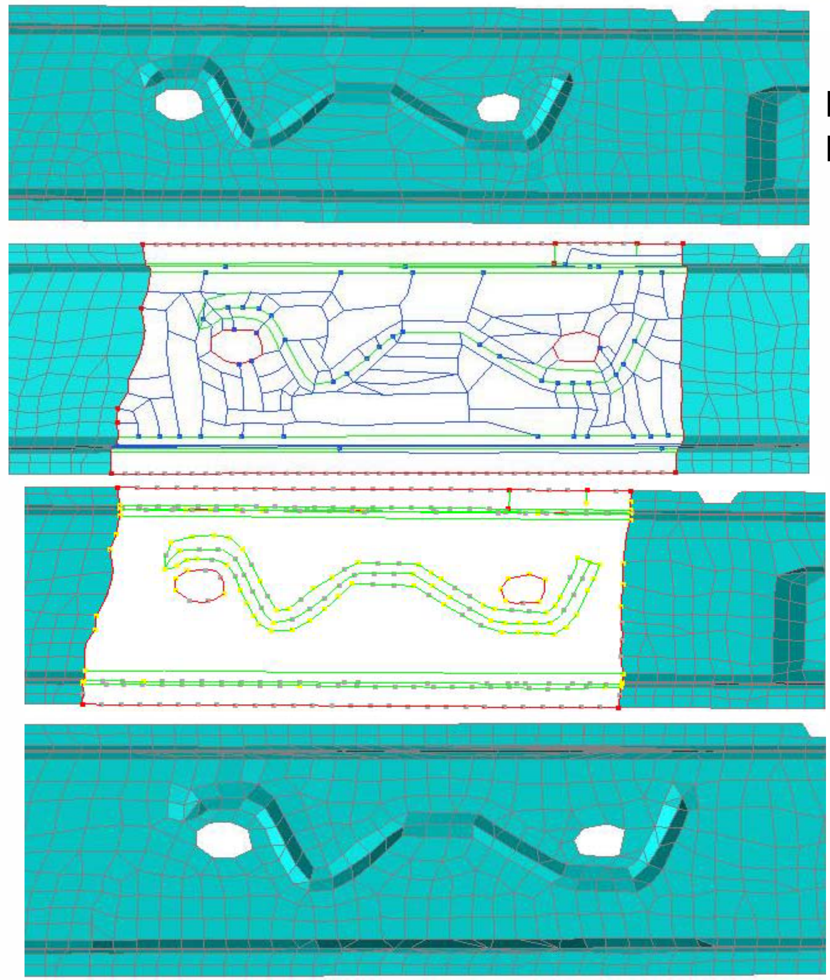
A user specified tolerance identifies the distance at which the beam changes will be blended into the rest of the structure (e.g. into the joints).



Fixing a mesh using reverse engineering

Shown to the right is a three step process.

1. Elements to Surface. This automatic process creates surfaces within a specified surface and edge tolerance. The boundary pitch is automatically made to match the connecting mesh.
2. Defeature. Use existing curve suppression tools.
3. Automesh. Use existing meshing tools.



Distorted Morphed Mesh

Reverse Engineer (Mesh to Surfaces)

Defeature

Automesh

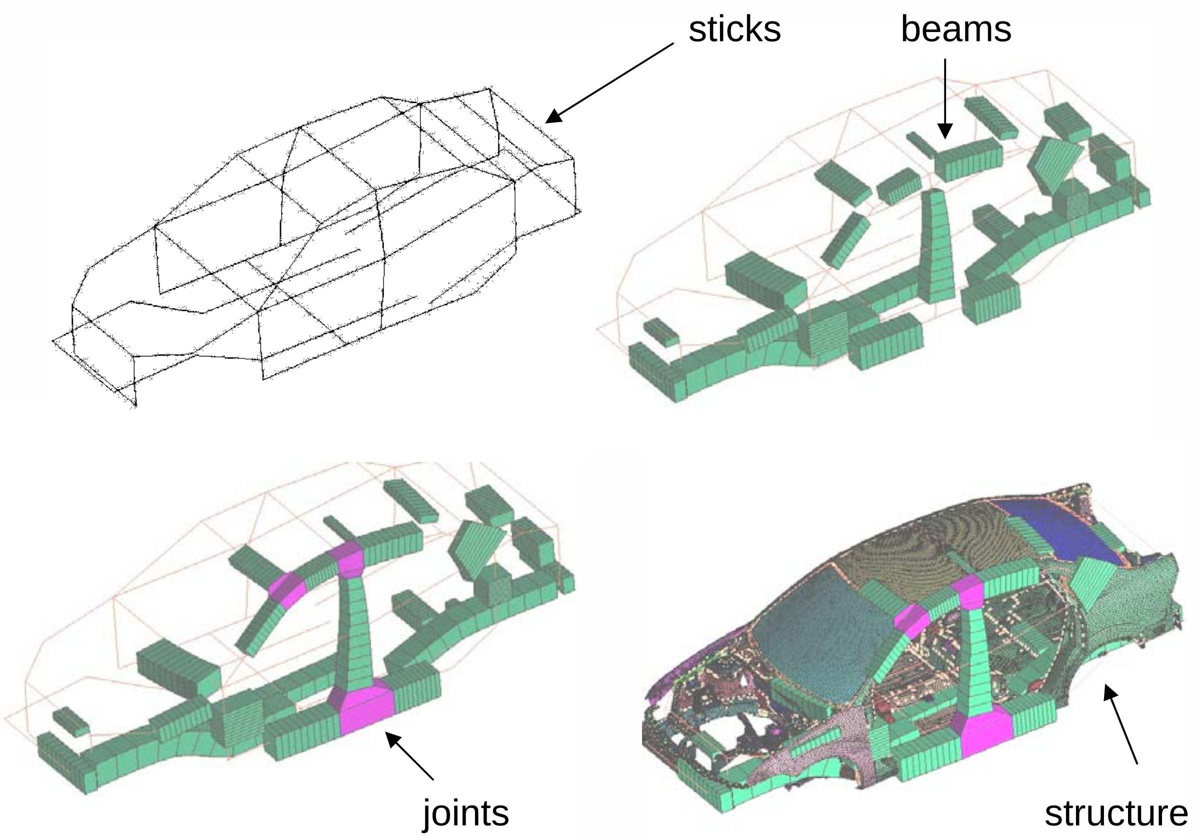
Structured Morphing – Systematic approach to morphing structures.

Ford

Structured Morphing is a concept that is still being explored. It uses Associative Morphing as an engine and leverages several other technologies.

The basic premise is to generate a stick representation of the structure. Link beam sections to the sticks and connect joints to the ends of the beams. Lastly, relate the entire structure to the beams and sections.

Partitioning a structure in this way supports the ability to “swap” portions of one vehicle design to another. This is done by using the blocks as cutting planes and using morphing to fit new designs into position.



Challenges

- Associative Morphing Prototype needs to be developed into a production ready tool
  - Improve robustness
  - Improve usability

- Further exploration of Structured Morphing needed
  - Improved methods for creating stick, beams, and joints
  - Need to create a “panel” object (to support floors & roofs).
  - Need better capability to stitch non-matching meshes
  - Support bookshelving of partitioned designs

Next Steps - MSC.SOFY

- Production ready Associative Morphing
- Production ready Mesh Reverse Engineering

- Phase 1 – Current Development (Q3 2005)
  - Generalized Control entity (Point, Curve, Surface, Solid)
  - Sticky Zones / Rigid Bodies
  - Influence Blocking
  - Linear Constraints
  - Reverse Engineering 1.0
  - Documentation &Tutorials

- Phase 2 (Q1 2006)
  - Linked Morphs
  - Advanced Constraints
  - Reverse Engineering 2.0