The Shape Matching Element Method: Direct Animation of Curved Surface Models

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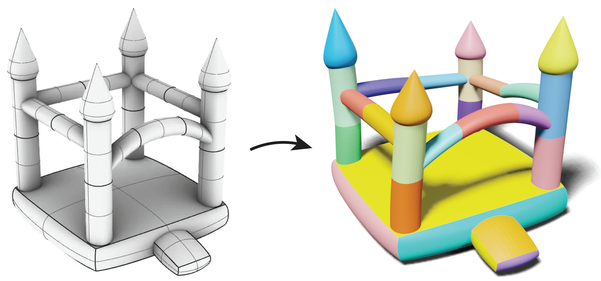
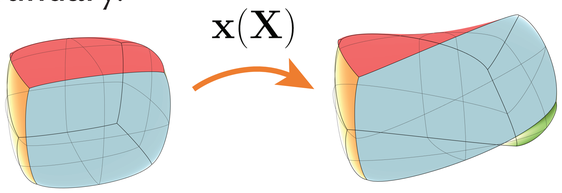
Abstract

We introduce a method for direct physics-based animation of volumetric curved surface models, represented by NURBS surfaces, that is completely meshless, robust to gaps and overlaps in geometry, and compatible with standard material models.



Method

We use shape matching on the boundary NURBS to produce a polynomial describing the deformation of each NURBS. The deformation map for interior points is constructed by blending the polynomials on the boundary.

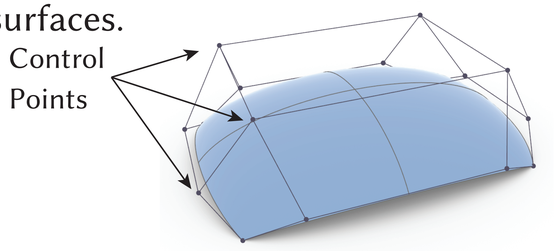


Deformation Map

$$\mathbf{x}(\mathbf{X}) = \sum_{i}^{n} \underbrace{w_i(\mathbf{X})}_{\text{Weights}} \underbrace{P_i(\mathbf{X})\mathbf{c}_i}_{\text{Polynomials}}$$

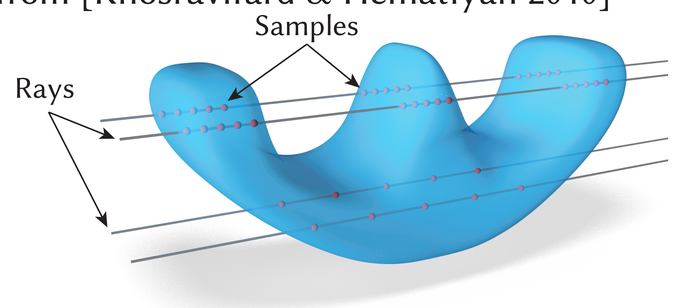
Surface Only Discretization

Degrees of freedom are the control points of the NURBS surfaces.



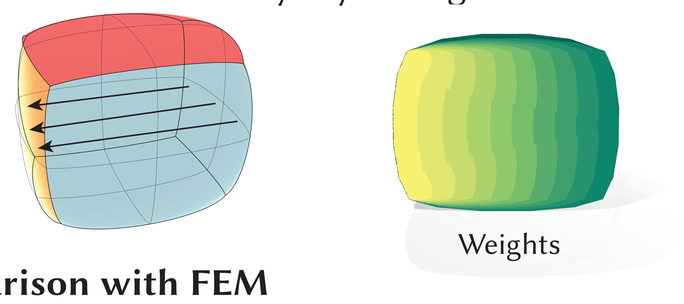
Meshless Quadrature

Use meshless raycasting method based on method from [Khosravifard & Hematiyan 2010]



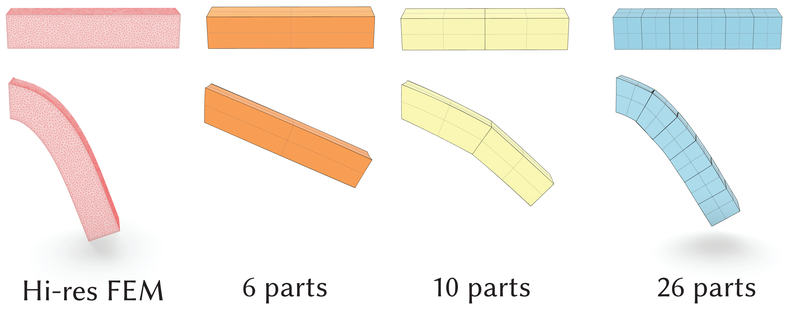
Blending Weights

Meshless construction by raycasting



Comparison with FEM

Adding more NURBS parts to the beam model shows that SEM qualitatively converges to the FEM solution.

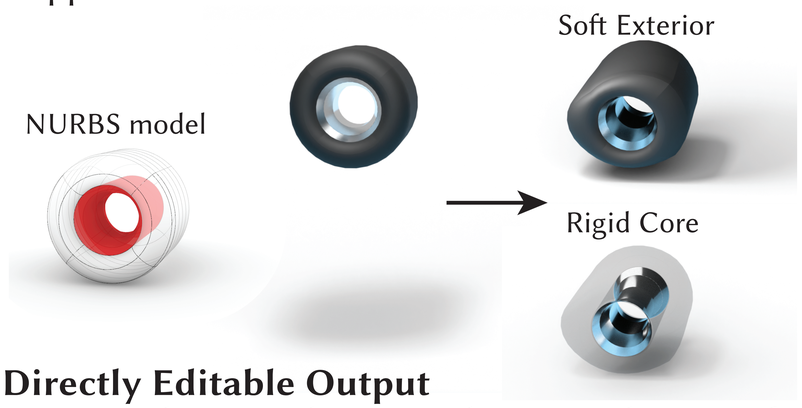


Handles Large Deformation

With relatively few NURBS parts, we can simulation this beam twisting with no instabilities.

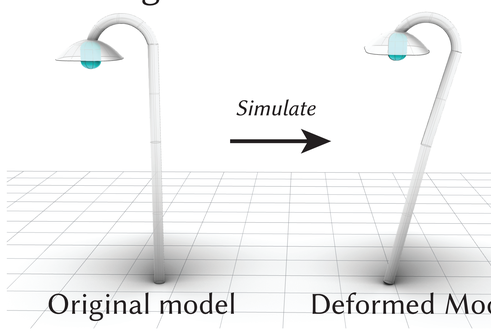
Heterogenous Materials

Supports simulation of multi-material models



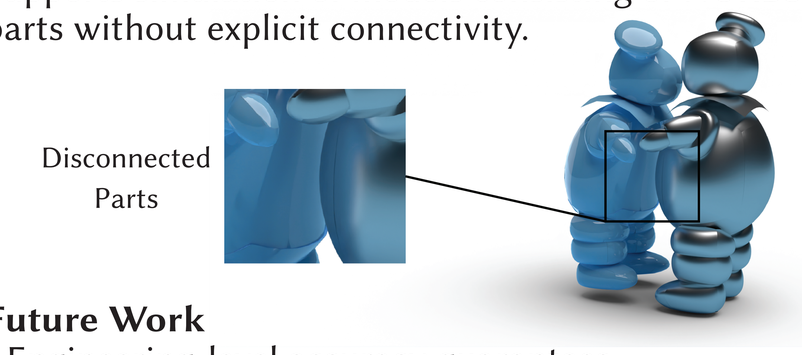
Directly Editable Output

SEM simulates on the original NURBS degrees of freedom, so the output is digestible by the same software used to design the model.



Robust to Gaps and Self-Intersections

Supports simulation of models consisting of NURBS parts without explicit connectivity.



Future Work

- Engineering-level accuracy guarantees
- Explore more robust shape matching
- Simulation of models with multiple boundary representations.

Reference: [1] Amir Khosravifard, & Mohammad Rahim Hematiyan (2010). A new method for meshless integration in 2D and 3D Galerkin meshfree methods. *Engineering Analysis with Boundary Elements, 34(1), 30-40.*