Model reduction for dynamics on deformable complex surfaces.

Shaimaa Monem¹, Peter Benner¹, and Christian Lessig²

¹Max Planck Institute for Dynamics of Complex Technical Systems
²Institute for Simulation and Graphics, Otto-von-Guericke Universität Magdeburg

Dynamics of deforming surfaces, 2-dimensional objects embedded in 3D spaces, are governed by Newton’s law of motion for mechanical systems under internal and external forces, \( \mathbf{M}\ddot{\mathbf{q}}(t) = f_{\text{int}}(\mathbf{q}(t)) + f_{\text{ext}} \).

Simulating such structures is very expensive, especially under real time changing internal forces acting on vertices and/or their connected faces, particularly when the meshes under consideration include hundreds of thousands of vertices.

Exploiting the variational formulation of the system, positions \( \mathbf{q}(t) \in \mathbb{R}^{N \times 3} \) of vertices at different time steps, can be written as a minimizer that compromises between both associated momentum and potential energies. The computations then divided into many parallel local nonlinear solves and one linear global solve; this is known as the projective dynamics scheme [2].

The nonlinear internal forces, such as bending and strain, express and control the material behavior of the surface as a geometrical object and they require re-computation at every time step. External forces typically remain constant during computations. We explore different model reduction techniques to tackle the computational complexity of simulating deformable surfaces. To find a low dimensional subspace, we consider different candidate methods, namely localized sparse-PCA [4] and localized quaternion-PCA [1]. We also compare to skinning subspaces which have been earlier used [3]. Figure 1 bellow shows the first 8 sparse localized PCA components extracted using a simple simulation for the bunny mesh falling under gravitational forces.

![Figure 1: First 8 sparse-PCA components under gravitational force simulation for a bunny object. Each component is localized around the vertex that shows the largest change. Normalized weights associated to different components are shown in blue.](image)

References


