

Dynamic Drape Simulation by Solid-shell Element and Rotation-free Triangle

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Abstract

Drape simulation finds its applications in fashion design, e-commerce of clothing and production of animated movies. Fabric drapes are typical large displacement, large rotation and small strain problems. Compared with the conventional geometric non-linear shell analysis, computational drape analysis is particularly challenging due to the weak bending rigidity of fabric. The task has been undertaken by different approaches which include but not restrict to particle methods, finite element methods and rotation-free element methods. To avoid the stringent requirement on the particle distribution which leads to complications on modelling skew and curved fabric boundaries, the authors worked on finite element and rotation-free triangle methods.

Among various finite element formulations for shell analyses, solid-shell elements was adopted for two reasons. Firstly, solid-shell elements do not possess rotational degrees of freedom and, thus, the complications arising from finite rotations can be exempted. Secondly, previous studies have indicated that solid-shell elements can often undertake larger load increments without divergence than the equivalent degenerated shell elements. Alternately, solid-shell elements often consume less iterations than the equivalent degenerated shell elements for the same load increment. While solid-shell elements using assumed natural shear and thickness strains perform very well in most, if not all, popular geometric nonlinear shell benchmark problems, they may converge to solutions which show non-physical sharp folds due to the interpenetration of the top and bottom shell surfaces, see Figure 1 [Sze and Liu, 2007]. Nevertheless, the interpenetration can be avoided if the product of the curvature and the element size is not excessively large. In this light, an adaptive mesh subdivision method based on the 1-4 splitting was developed. The subdivision also serves to resolve details of deep folds. To link elements at different subdivision levels, element patches are formed by quadrilateral and triangular solid-shell elements, see Figure 2. To reduce the spurious dynamic oscillation induced by newly inserted nodes along the dynamic simulation process, the discrete Kirchhoff condition was devised in a corotational setting to determine the related nodal variables [Xie, Sze and Zhou, 2015].

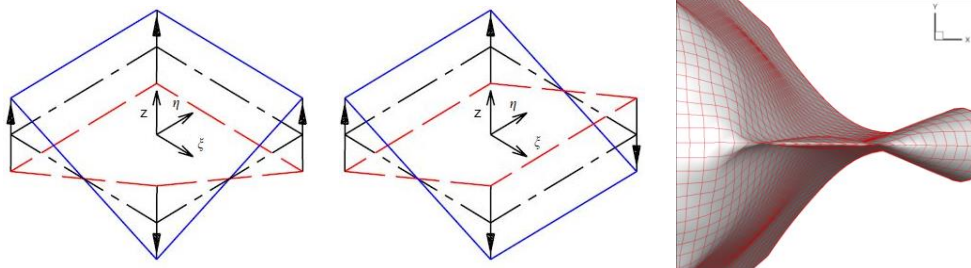


Figure 1. The interpenetration of the top and bottom element surfaces. Non-physical sharp folds formed as a result of the interpenetration.

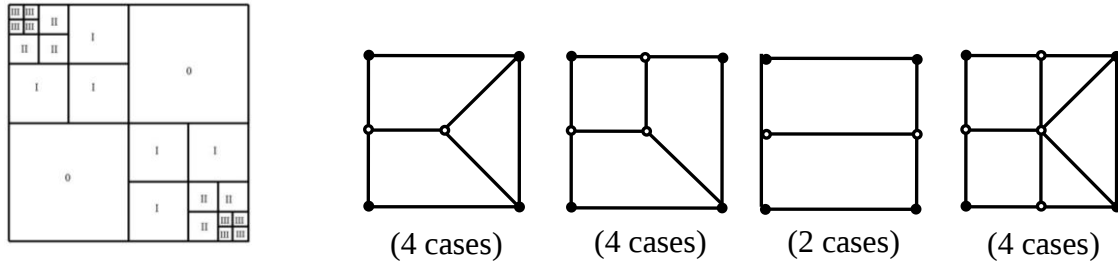


Figure 2. Multilevel mesh formed by 1-4 splitting and the employed element patch for interfacing elements of different subdivision level.

In the rotation-free element method, a rotation-free triangle was developed. Same as solid-shell elements, the triangle possesses no rotational degrees of freedom. Its bending response based on a six-node quadratic interpolation of transverse deflection using an overlapping element concept and is extended to large displacement/rotation analyses by using a corotational framework. The formulation is simple and efficient yet its accuracy is competitive with respect to other rotation-free triangles [Zhou and Sze, 2012]. Nevertheless, non-physical folds would also be predicted if the product of the curvature and the element size is excessive, see Figure 3. They are due to a zero energy mode caused by the CST approximation of the membrane energy. The drawback was later rectified by using the six-node displacement interpolation for deriving the membrane strain, see Figure 3 [Sze & Zhou, 2015]. A global adaptive remeshing scheme was also developed for efficient prediction of deep folds.

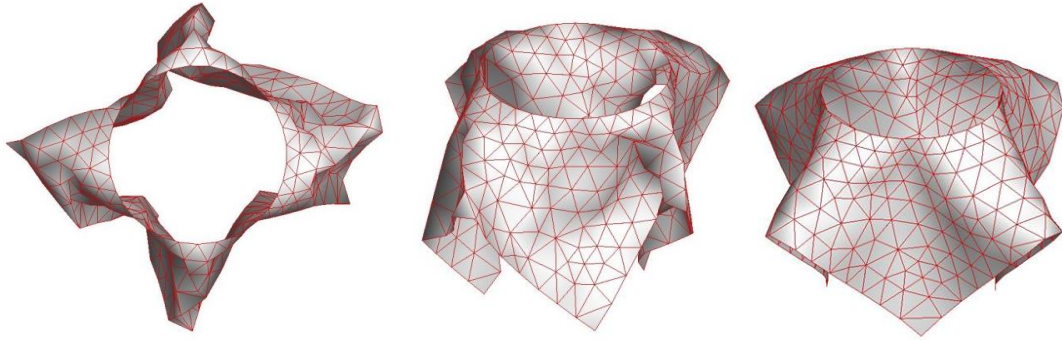


Figure 3. (Left and Middle) Non-physical folds developed in the rotation-free triangle. (Right) They are eliminated by enhancing the interpolation zone for the membrane strain.

Typical static and dynamic drape problems were considered by using the solid-shell element and the rotation-free triangles, see Figures 4 to 7. Other problems including collision, cloth sewing and skirt on moving manikin were also examined. Both methods can yield realistic predictions. Discussions on their relative pros and cons will be discussed towards the end of the presentation.

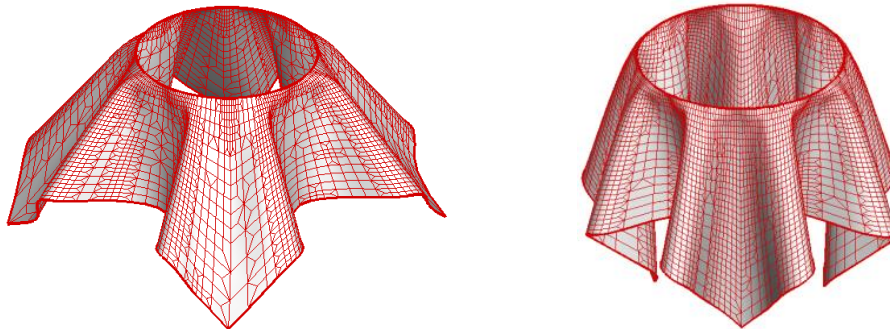


Figure 4. Deep drapes predicted by solid-shell elements and reversible adaptive subdivision at two instants of the dynamic drape process.

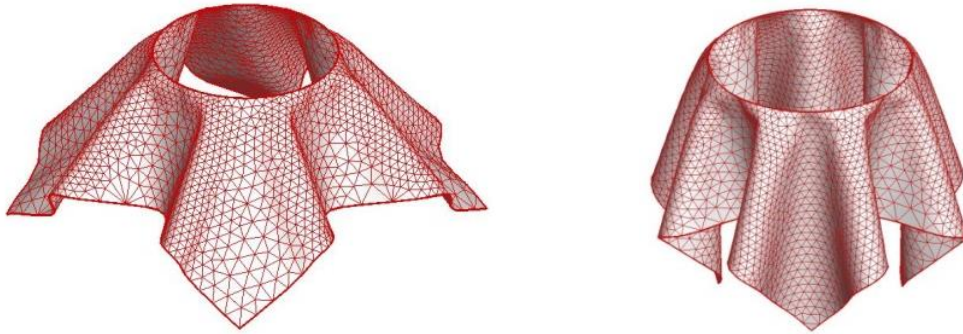


Figure 5. Deep drapes predicted by rotation-free triangle and adaptive remeshing at two instants of the dynamic drape process.

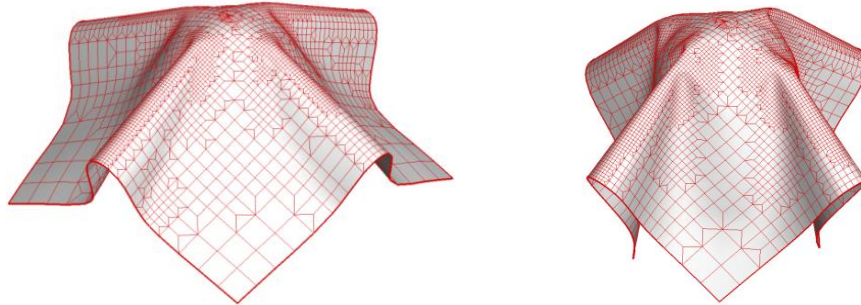


Figure 6. Square fabric sheet over a sphere predicted by solid-shell elements and reversible adaptive subdivision method at two instants of the dynamic drape process.

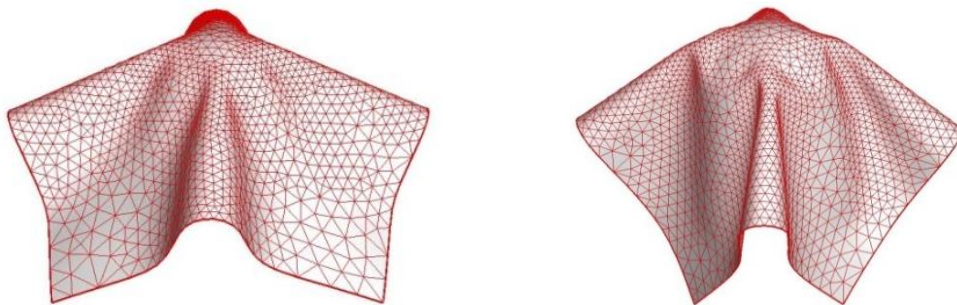


Figure 7. Square fabric sheet over a sphere predicted predicted by rotation-free triangle and adaptive remeshing at two instants of the dynamic drape process.

References

- Sze, K.Y. and Liu, X.H. (2007) Fabric drape simulation by solid-shell finite element method. *Finite Elements in Analysis & Design* **43**: 819-838.
- Sze, K.Y. and Zhou, Y.X. (2015). An efficient rotation-free triangle for drape/cloth simulations - Part I: model improvement, dynamic simulation and adaptive remeshing. *Inter J Comput Methods* (Accepted)
- Xie, Q., Sze, K.Y., Zhou Y.X. (2015) Drape Simulation using Solid-shell Elements and Adaptive Mesh Subdivision, *Finite Elements in Analysis & Design* (Under review)
- Zhou YZ, Sze KY (2012). A geometric nonlinear rotation-free triangle and its application to drape simulation. *Inter.J. Numer.Methods Engrg.* **89**: 509-536.