Fine tuning of Catmull-Clark subdivision surfaces: solving shape problems via spectral analysis

Lucia Romani [1]

[1] *Dipartimento di Matematica e Applicazioni, Università di Milano-Bicocca.* lucia.romani@unimib.it

Catmull-Clark subdivision surfaces [3] are a generalization of tensor-product cubic B-spline surfaces, obtained by applying the most widely used primal subdivision algorithm for quadrilateral meshes of arbitrary manifold topology. Indeed, besides playing an important role in geometric modeling [1] and computer animation [4], Catmull-Clark subdivision surfaces have been recently used also in conjunction with iso-geometric finite element analysis [2, 6].
In this talk, after introducing the so-called hybrid block-circulant algebra to conveniently represent the local matrices of any primal subdivision algorithm [5], we show how, with the help of spectral analysis, the extraordinary rules of Catmull-Clark subdivision algorithm can be suitably modified in order to improve the quality of the resulting limit surfaces in the vicinity of extraordinary vertices of any valence. Indeed, while the original proposal of Catmull-Clark algorithm [3] suffers from a misbehaviour of the generated limit surfaces at and near extraordinary points, the surfaces provided by a suitable modification of the standard refinement rules can prevent problems like unbounded increase of curvature, severe shape dissimilarity with the underlying control mesh as well as deterioration of the visual smoothness caused by the so-called polar rendering artifacts. Comparisons between different proposals of modified extraordinary rules will be presented.

References

[1] M. Antonelli, C.V. Beccari, G. Casciola, R. Ciarloni, S. Morigi, *Subdivision surfaces integrated in a CAD system*, Computer-Aided Design 45 (2013) 1294–1305.

[2] D. Burkhart, B. Hamann, G. Umlauf, *Iso-geometric finite element analysis based on Catmull-Clark subdivision solids*, Computer Graphics Forum, 29 (2010) 1575–1584.

[3] E. Catmull, J. Clark, *Recursively generated B-spline surfaces on arbitrary topological meshes*, Computer Aided Design, 10(6) (1978) 183–188.

[4] T. DeRose, M. Kass, T. Truong, *Subdivision surfaces in character animation*, Proceedings of the 25th annual conference on Computer graphics and interactive techniques - SIGGRAPH '98 (1998) 85–94.

[5] M. Donatelli, P. Novara, L. Romani, S. Serra-Capizzano and D. Sesana, *Surface Subdivision Algorithms and Structured Linear Algebra: a Computational Approach to Determine Bounds of Extraordinary Rule Weights*, Technical Report 2016-012, Division Scientific Computing, Dept. Information Tech. - Uppsala University.

[6] Q. Pan, G. Xu, G. Xu and Y. Zhang, *Isogeometric analysis based on extended Catmull-Clark subdivision*, Computers & Mathematics with Applications, 71(1) (2016) 105–119.