Imperial College
London

PRAgMaTIc - Parallel Anisotropic Adaptive Mesh Toolkit

Georgios Rokos, Gerard Gorman
Department of Computing, Department of Earth Science and Engineering
Imperial College London

Introduction

The numerical methods used to model complex geometries required by many scientific applications (e.g. climate prediction, simulation of cardiac electrophysiology) often favour the use of unstructured meshes and finite element discretisation methods over structured grid alternatives. This flexibility introduces complications, such as the management of mesh quality and additional computational overheads arising from indirect addressing. Mesh adaptivity methods ([3, 1]) provide an important means to control solution error by focusing mesh resolution in regions of the computational domain where it is required. PRAgMaTIc is an open-source mesh adaptivity framework, built with large-scale multiprocessing in mind. In order to ensure thread-safe execution, we devised a novel approach which combines an older proposal by Freitag et al. [2] with low-level intervention in mesh data structures. PRAgMaTIc supports both NUMA (via OpenMP) and distributed-memory (via MPI) systems. Main focus of our work is currently on 2D mesh adaptivity; however, work on 3D adaptivity and SIMT-style massive parallelism (CUDA/OpenCL) is also in progress. PRAgMaTIc can be downloaded from Launchpad: https://launchpad.net/pragmatic.

Adaptive algorithms

Coarsening

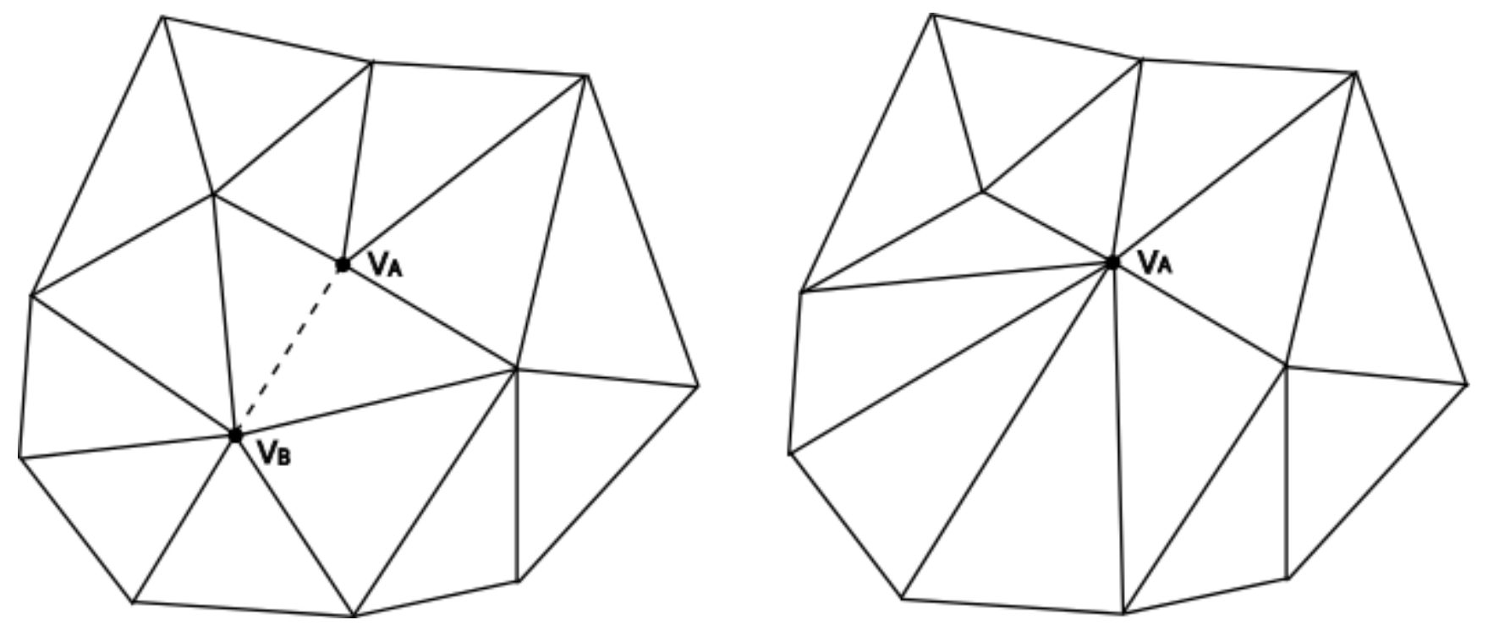

Figure 1: Edge collapse: vertex V_B collapses onto V_A, removing the dashed edge and the corresponding elements from the mesh.

Refinement

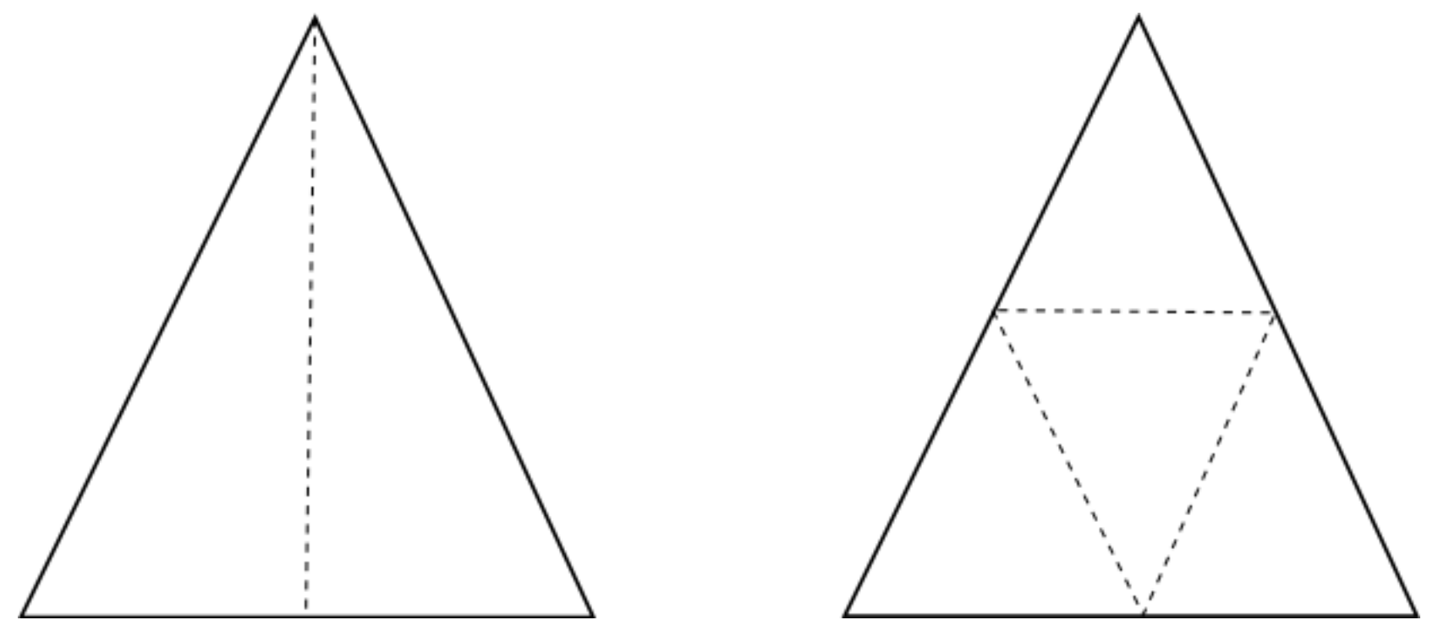

Figure 2: Edge refinement: edges can be split, leading to bisection (left figure) or regular refinement (right figure) of elements, which increases local mesh resolution.

Swapping

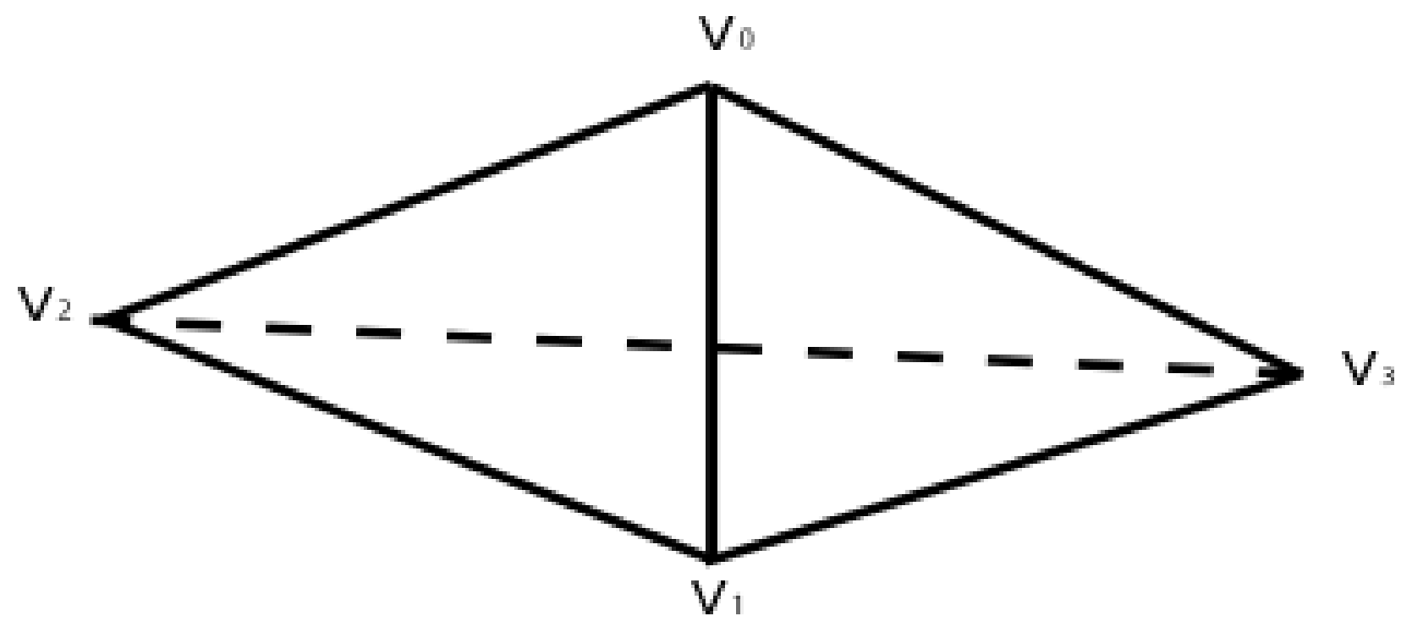

Figure 3: Edge swapping: edges shared between two elements can be flipped if doing so produces elements of higher quality than the original ones.

Smoothing

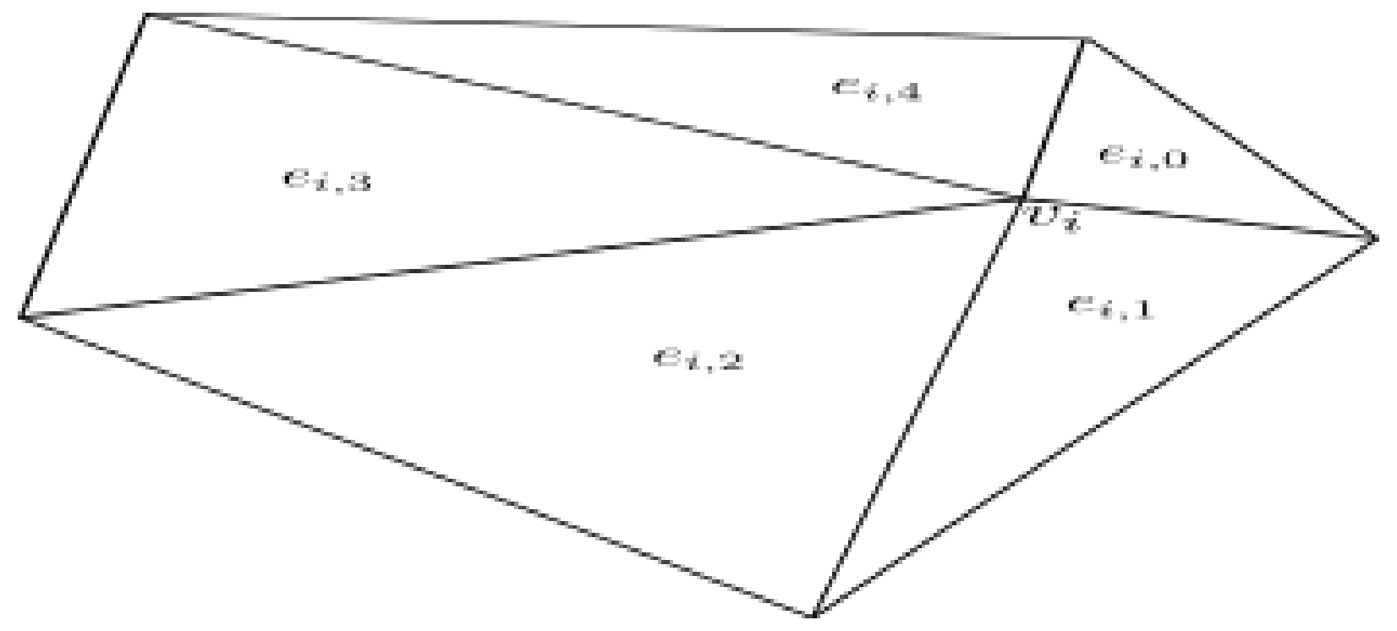

Figure 4: Optimisation-based vertex smoothing: a vertex u_i is relocated to a new position so that the quality of the worst element among $[e_{i,0}..e_{i,5}]$ is maximised.

Results

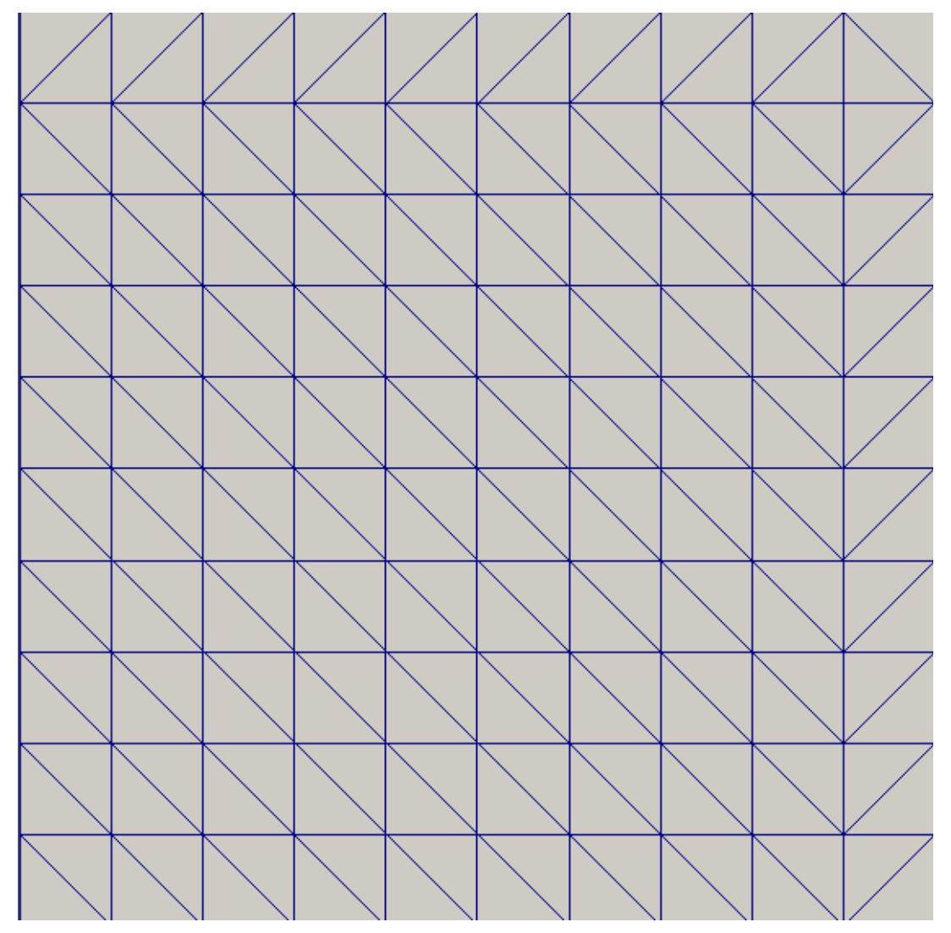

Figure 5: Initial, auto-generated mesh.

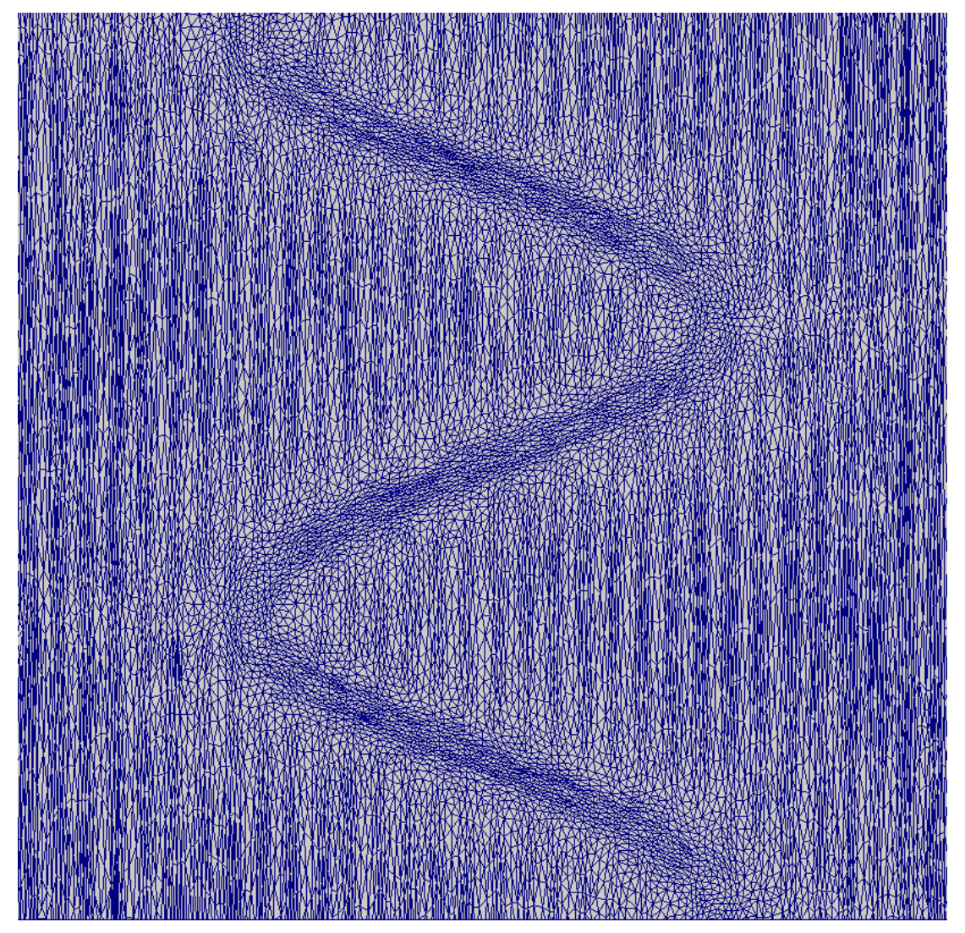

Figure 6: Mesh adapted to some error metric.

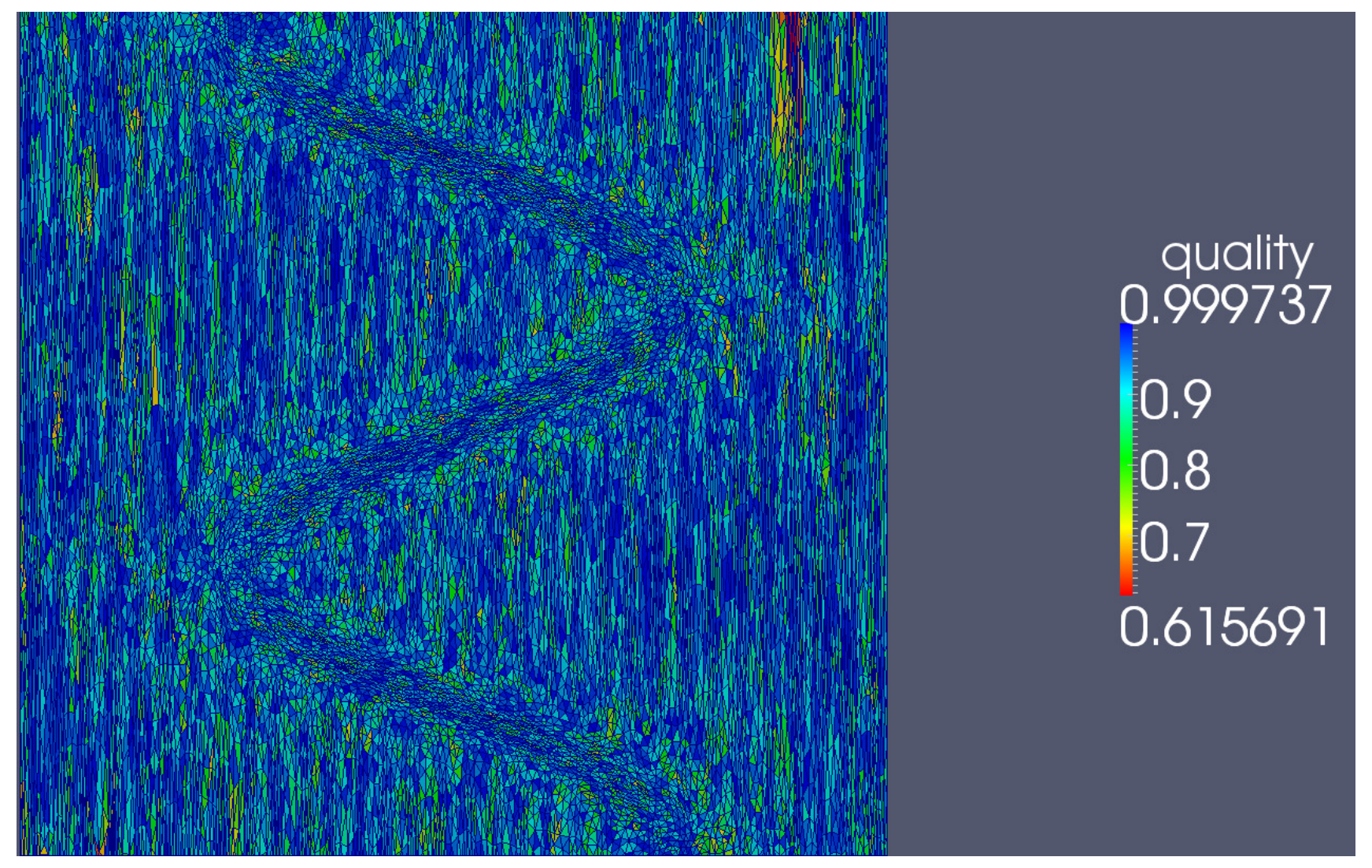

Figure 7: Quality of adapted mesh.

Conclusions

PRAgMaTIc produces high-quality adapted meshes from typical, auto-generated input meshes. Average element quality is > 0.9, whereas worst element quality is > 0.6 (ideal quality is 1.0). Performance and scalability are being tuned at the moment.

References

[1] L. Freitag, M. Jones, and P. Plassmann. An efficient parallel algorithm for mesh smoothing. In *Proceedings of the 4th International Meshing Roundtable, Sandia National Laboratories*, pages 47–58. Citeseer, 1995.

[2] L. F. Freitag, M. T. Jones, and P. E. Plassmann. The Scalability Of Mesh Improvement Algorithms. In *IMA VOLUMES IN MATHEMATICS AND ITS APPLICATIONS*, pages 185–212. Springer-Verlag, 1998.

[3] X. Li, M. Shephard, and M. Beall. 3d anisotropic mesh adaptation by mesh modification. *Computer methods in applied mechanics and engineering*, 194(48-49):4915–4950, 2005.

Acknowledgements

We would like to thank Fujitsu Laboratories of Europe Ltd and EPSRC grant number EP/I00677X/1 for supporting this work.

AMCG Applied Modelling and Computation Group
Soft