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POLYLLA: Polygonal meshing algorithm based on terminal-edge regions

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The problem

Polylla is a polygon mesh generator that generates meshes with arbitrary shape polygon. High-quality polygonal meshes are essential for Virtual Element Method (VEM) simulations. VEM has the potential to accommodate arbitrary polygons, simplify meshes, and potentially accelerate simulations. Therefore, the development of automatic mesh generation algorithms for VEM is crucial for achieving efficient and high-quality simulations in a variety of applications, such as earthquake simulation, fluid simulation, and so on.

Methodology

The primary objective is to design new algorithms for generating polygonal or polyhedral meshes with cells of arbitrary shapes that are efficient, robust, scalable (in parallel), and meet quality criteria for the VEM. To achieve this goal, we have developed the Polylla mesh generator [1, 2], along with a compact [3] and a GPU-parallel version to reduce memory usage and speed up the algorithm. We have also conducted a comparison of over 500 Polylla meshes with Voronoi meshes using the VEM in several complex geometric domains.

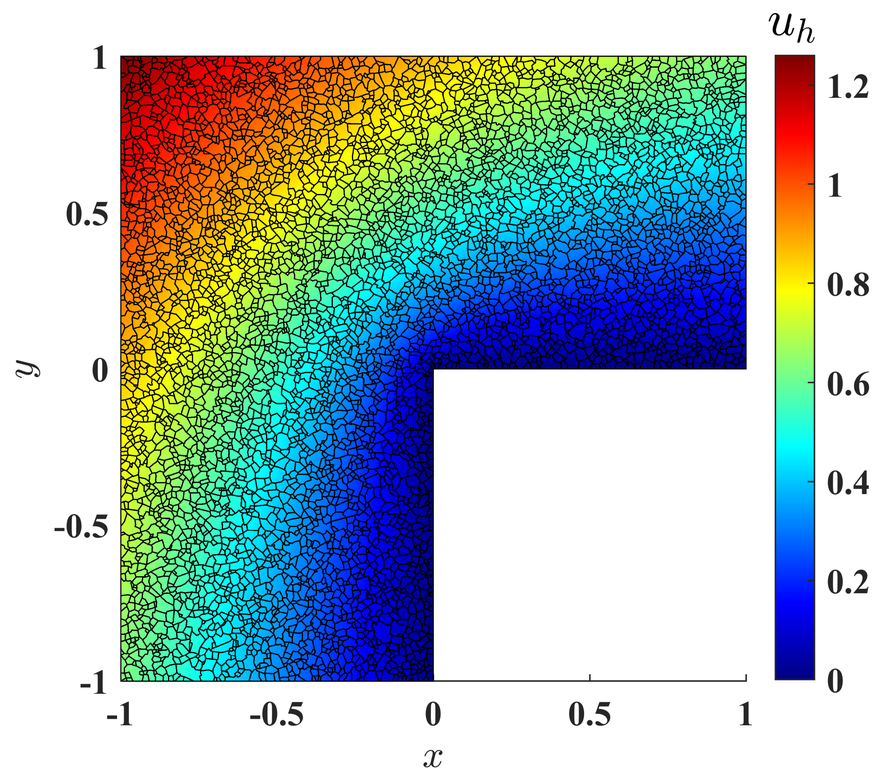

Figure 1. Contour plot of Polylla mesh to get the VEM solution of a the Laplace equation.

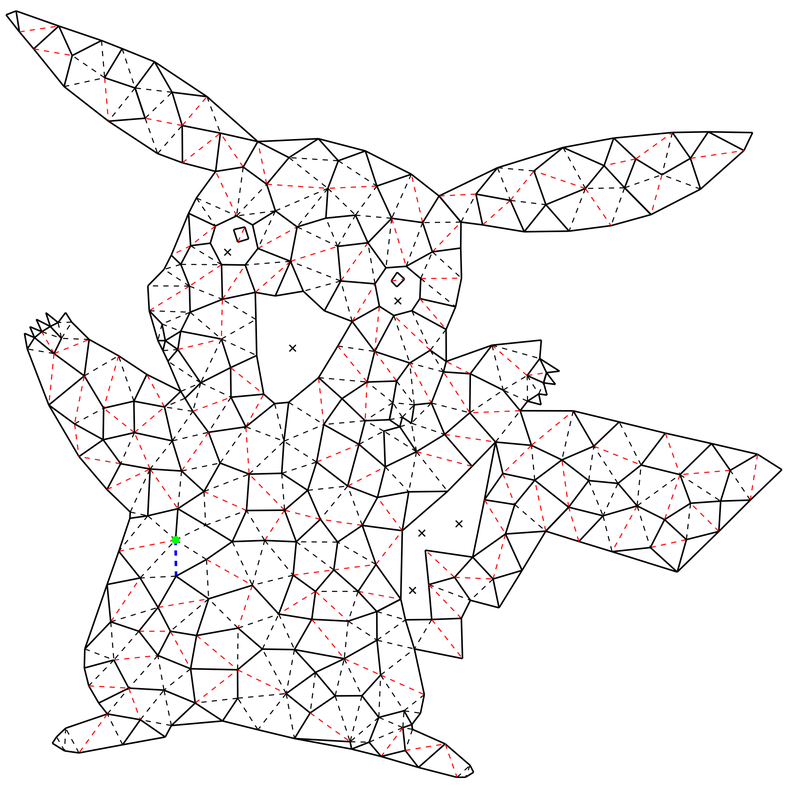

Figure 2. Labeled triangulation, red edges are terminal-edges

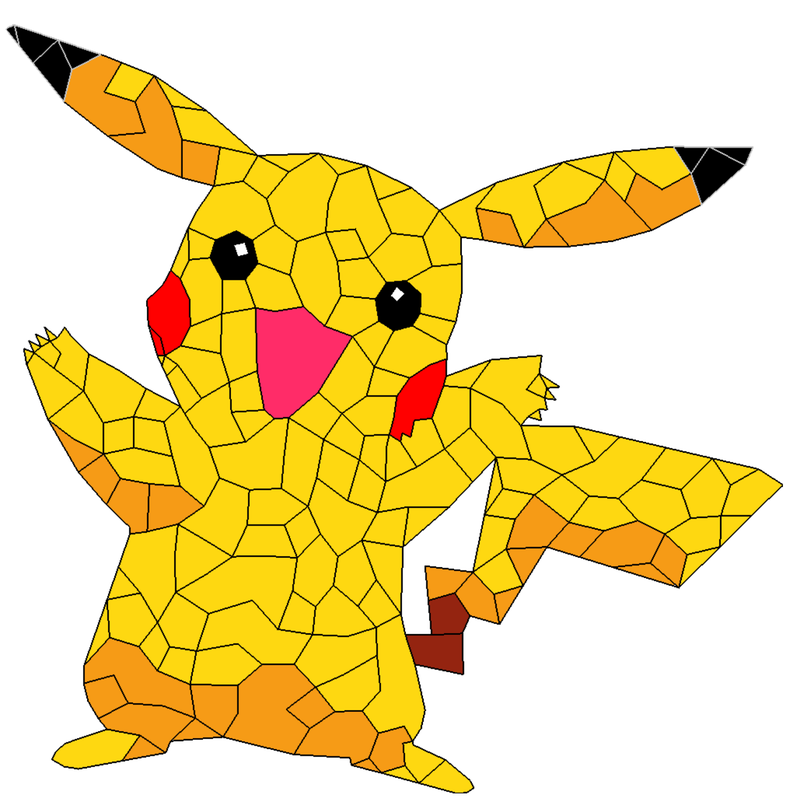

Figure 3. Polylla Mesh

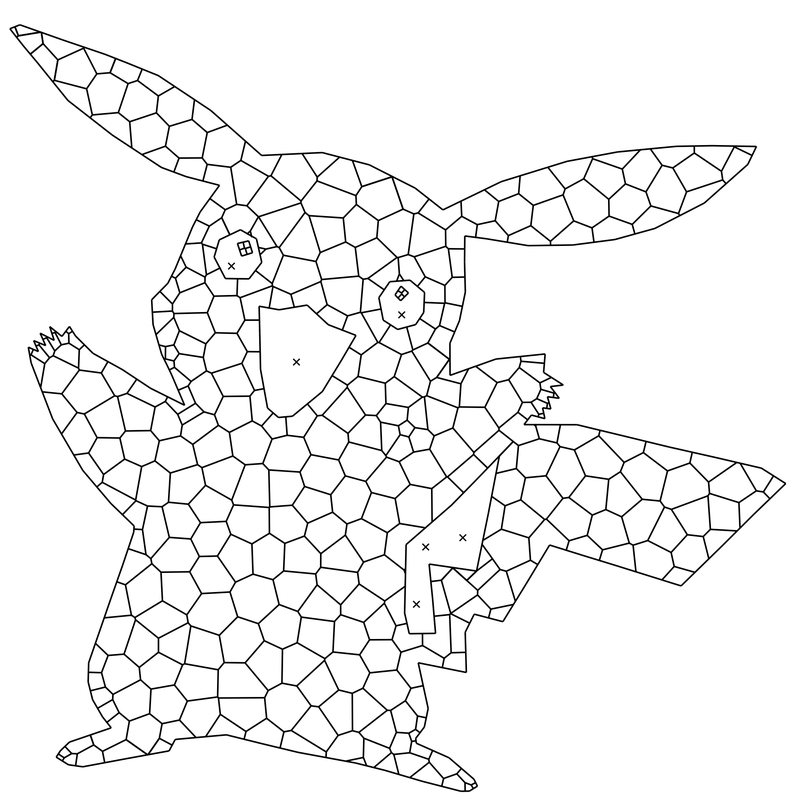

Figure 4. Voronoi Diagram

Results

- A new kind of polygonal meshes composed of less polygons and points than constrained Voronoi meshes for the same input.
- Polylla meshes show a similar computational cost in time and accuracy to Voronoi meshes in experiments performed with the VEM.
- The parallel GPU version has managed to accelerate the performance of generation of Polylla meshes $90\times$ faster compared to its sequential version.
- The compact version of Polylla allows us to compress 99% the memory for the topological data inside of the Polylla meshes and reduce the memory cost necessary for the generation of the meshes by a factor of 3.

Conclusion and Future Works

We developed a robust tool for the scientific community to discretize complex domains in two dimensions. This meshing tool works with meshes of arbitrary size and can be accelerated on GPUs. Future research will involve:

- Extend Polylla to surface meshes
- Develop a 3D volumetric version
- Develop refinement and optimization algorithm for arbitrary shape polygons
- Test Polylla in a real world problem

References

- [1] Salinas-Fernández, S., Hitschfeld-Kahler, N., Ortiz-Bernardin, A. et al. POLYLLA: polygonal meshing algorithm based on terminal-edge regions. Engineering with Computers 38, 4545–4567 (2022). https://doi.org/10.1007/s00366-022-01643-4
- [2] Ortiz-Bernardin, A, Silva-Valenzuela, R, Salinas-Fernández, S, Hitschfeld-Kahler, N, Luza, S, Rebolledo, B. A node-based uniform strain virtual element method for compressible and nearly incompressible elasticity. Int J Numer Methods Eng. 2023; 124(8): 1818–1855. doi:10.1002/nme.7189
- [3] Salinas-Fernández, S., Fuentes-Sepúlveda, J., y Hitschfeld-Kahler, N., “Generation of polygonal meshes in compact space,” en International Meshing Roundtable Workshop (IMR), (Amsterdam, Netherlands), 2023.