A generic framework for out of core watertight surface reconstruction

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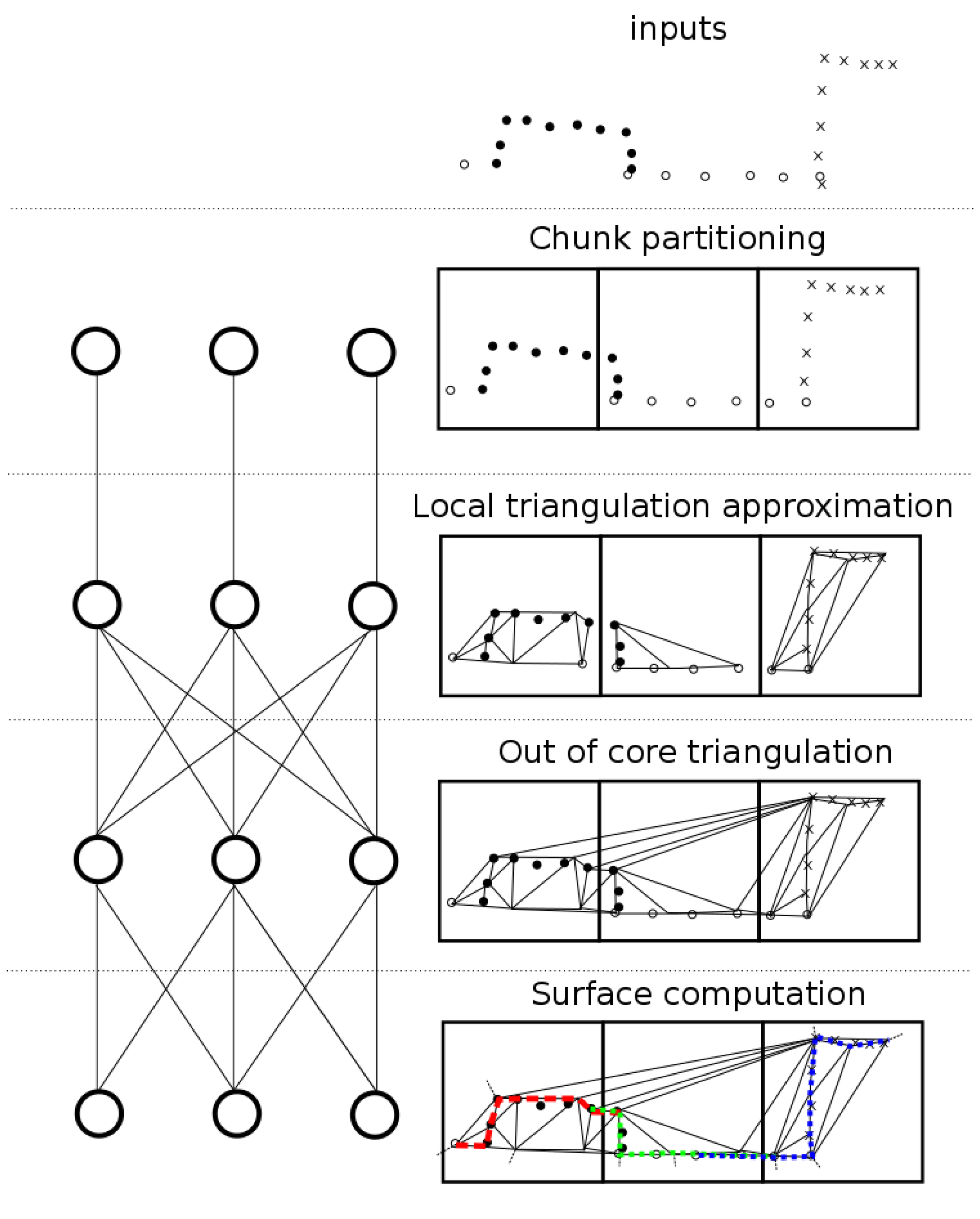
Introduction

Many watertight surface reconstruction approach are based on an indoor / outdoor segmentation of a Delaunay triangulation where the resulting surface is represented by the interface between the indoor / outdoor areas. When data becomes important and need to be processed separately, the watertightness of the surface cannot be guaranteed anymore. In order to produce a full watertight surface reconstruction on large datasets, we improved [1] by using an out of core Delaunay algorithm.

Main scheme

- The input is a set of Lidar-based 3D measurements or other inputs which are formulated as a set of mass functions that characterize the level of confidence to be inside or outside.
- The x,y space is discretized with a 2D grid where each point is aggregated to a chunk.
- A 3D Delaunay triangulation of each chunk is then computed.
- Neighbours triangulation in the grid are stitched, extra points can be added in order to break big tetrahedrons and reduce dependencies.
- The surface is then computed on each chunk following [1] by taking neighbour's chunk into account to ensure watertightness.

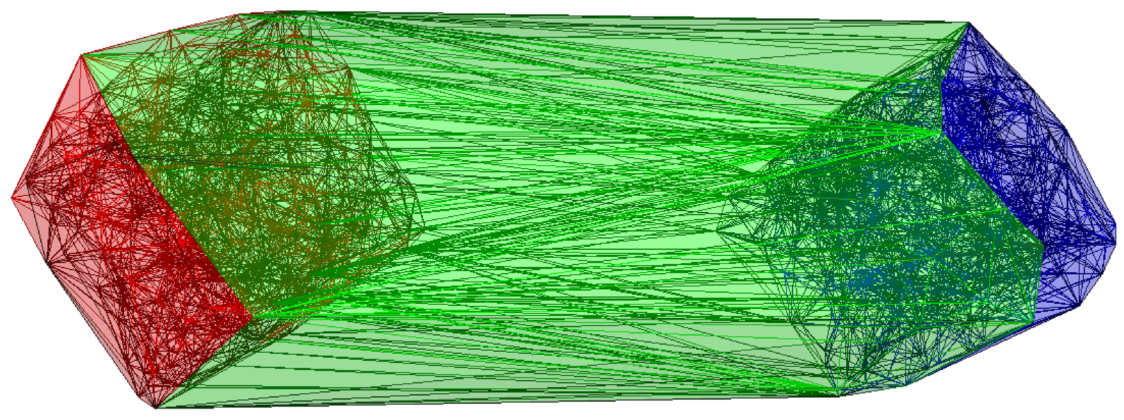


References

[1] L Caraffa, M Brédif, and B Vallet. 3d octree based watertight mesh generation from ubiquitous data. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, 40(3):613, 2015.

[2] Th Fischer. Edelsbrunner, h.: Algorithms in combinatorial geometry. springer-verlag, berlin–heidelberg–new york–london–paris–tokyo 1987. xv, 423 pp., hard cover dm 98,–isbn 3-540-13722-x. *Biometrical Journal*, 30(7):868–869, 1988.

Out of core triangulation



Problem Definition: Given two 3D Delaunay triangulations T1 and T2 split by a plane P, compute the Delaunay triangulation T = T1 U T2.

Aim: Design a new divide and conquer algorithm for 3D Delaunay triangulations which can be adapted to out-of core cloud computation.

Definitions:

- Delaunay Triangulation : A d-dimensional Delaunay triangulation is a d dimensional simplicial complex. For 3D case, it is composed of 3-simplices (cells, tetrahedra), 2-simplices (facets, triangles), 1-simplices (edges) and 0-simplices (vertices, points).
- Touching cell: A cell whose circumsphere touches to P.
- Conflicted cell : A cell whose circumsphere includes a conflicting cell. A conflicted cell cannot be a simplex in a Delaunay triangulation.
- Conflicting vertex : A vertex from T1 / T2 that lies within the circumsphere of a cell (conflicted) of T2 / T1.
- Purple vertices and edges : When convex hulls of T1 and T2 are considered as extended sources of red light, the facets that are lit become red and let the color of facets that remain in shadow be blue. The convex hull edges and vertices that are only passed by rays of light from the border between blue and red are therefore purple [2].

Observations: While merging two 3D Delaunay triangulations,

- Some cells of T1 / T2 might be deleted due to the conflicting vertices of T2 / T1.
- New cells (merging cells) are created which are incident to vertices both from T1 and T2.
- A cell of T is either
  - a non-conflicted cell of T1 (Theorem-I)
  - a non-conflicted cell of T2 (Theorem-I)
  - a merging cell

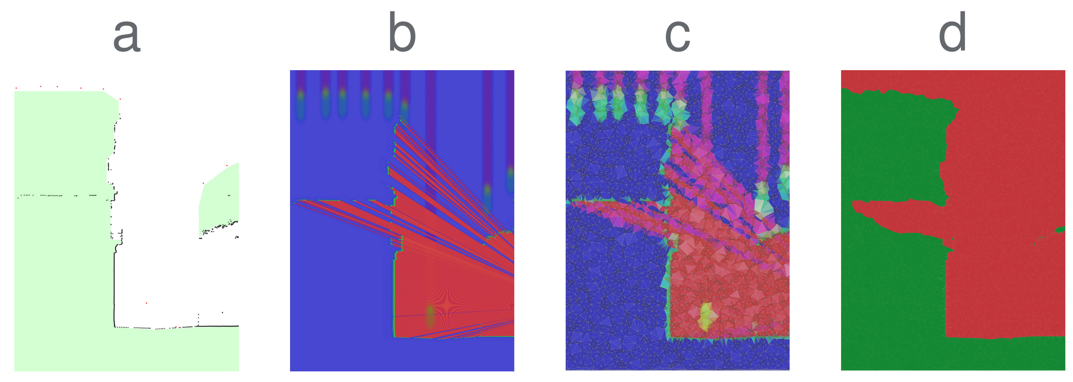
Algorithm:

- Compute touching cells for T1 and T2.
- Compute the vertices of T1 and T2 that are incident to touching cells.
- Perform in-sphere test on the touching cells of T1 / T2 w.r.t. the vertices of T2 / T1 computed in step-2. These tests determine the conflicted and non-conflicted cells of T1 / T2.
- Compute the vertices of T1 and T2 that are incident to conflicted cells.
- Compute the purple vertices.
- Insert the vertices of T1 / T2 computed in step-4 and step-5 into T2 / T1. This step removes the conflicted cells from T1 and T2 and generates the merging and complementary cells. Complementary cells completes T1 and T2 so that their outer boundary is a convex polytope.
- Generate T by removing the complementary cells and mapping the merging cells in T1 and T2.

Surface computation

Following the approach introduced in [1], the surface computation is decomposed in several step :

- For each point, a mass function that describe the occupancy of the space as indoor / outdoor is defined and merged thank to the Demptser-Shafer theory (b).
- For each tetrahedron, the mass function is integrated over the cell in order to have score for each tetrahedron to be inside or outside (c).
- The inside / outside segmentation is then computed with a graph-cut approach (d). The surface is the interface between inside and outside area.



Example in 2D. First, a slice of a 3d area recorded with ground based Lidar, the combined mass function, the normalized integral of the mass function on each cell. The resulting segmentation.

Results

The proposed approach is tested on a important dataset of 60,000,000 ground based Lidar points and 3,000,000 Aerial Lidar points.