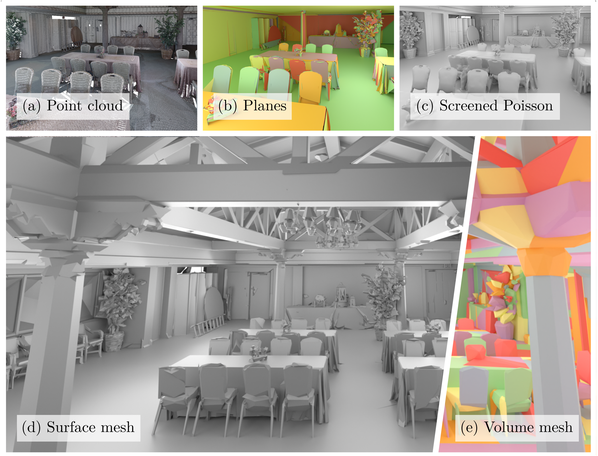
Concise Plane Arrangements for Low-Poly Surface and Volume Modelling

Raphael Sulzer and Florent Lafarge
Centre Inria d'Université Côte d'Azur

Motivation

- Plane arrangements are a useful tool for surface and volume modelling
- They use planar shapes detected from data measurements such as point clouds, and arrange them to form a polyhedral decomposition
- Subsequently, a surface or volume mesh can be extracted from the decomposition
- However, no current method for plane arrangement construction scales to more than 1.000 input planes
- We present an algorithm that can construct plane arrangements of complex objects and entire scenes, such as the one below, in a memory and time efficient manner

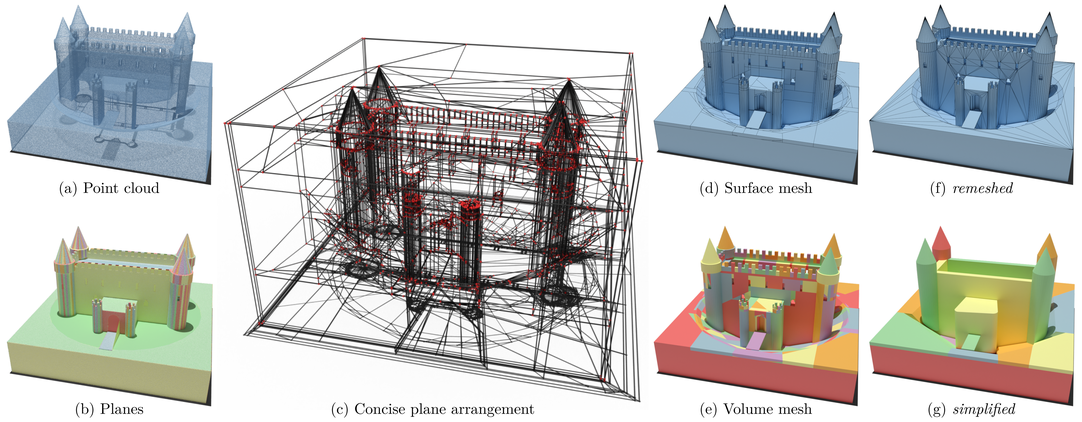


- Here, we construct a plane arrangement from 10M LiDAR points (a) and 40k planes (b) in around 35 minutes
- From our arrangement, we can e.g. extract a surface mesh (d) with 90k polygon facets, or a simplified volume mesh with 2500 convex polyhedra (e)
- For comparison, a Screened Poisson [Kazhdan13] reconstruction consists of over 6M triangles (c)

Project page

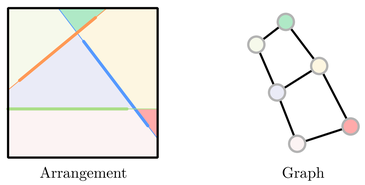
- Paper and supplementary material incl. comparisons with KSR [Bauchet19], RLPM [Chen23], CoACD [Wei22], BSP-Net [Chen20], Points2Poly [Chen22]
- Python library
- Datasets (Thingi10K [Zhou16], ShapeNet [Chang15], T&T [Knapitsch17])

Surface and volume modelling pipeline



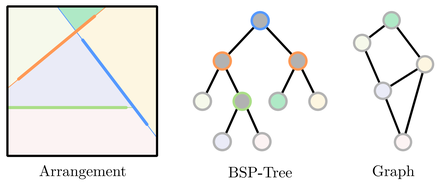
- Our algorithm transforms input points (a) and planes (b) into a concise plane arrangement (c) using an efficient ordering scheme for plane insertion
- Our surface extraction (d) and remeshing (f) strategy enables the extraction of a watertight, intersection-free polygon mesh, where each planar region consists of a single facet or a few Delaunay triangles for regions with holes
- Our volume extraction (e) and simplification (g) allows us to extract a volume mesh with intersection-free convex polyhedra or a simplified mesh with overlapping convex polyhedra

Plane arrangement construction



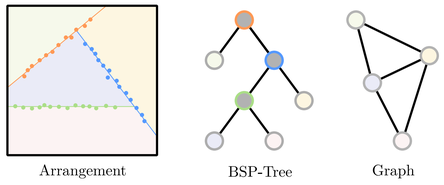
Exhaustive plane arrangement [Edelsbrunner86]

- Iteratively insert detected planes into the 3D domain
- Time complexity of $\mathcal{O}(n^3)$, with n being the number of input planes



Adaptive plane arrangement [Murali97]

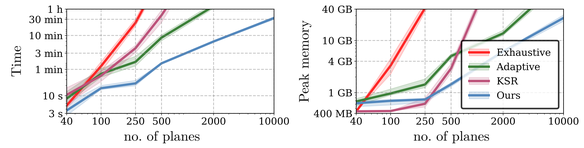
- Insertion operations are restricted to polyhedral cells that contain the associated planar shape
- No specific order for insertion operations



Our concise plane arrangement

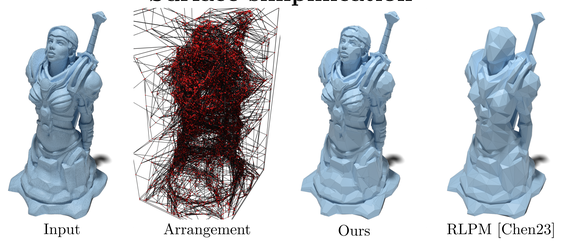
- Insert planar shapes that do not induce further splits on at least one side first
- Next, insert planar shapes that split point sets equally
- Use orientation tests to hierarchically cluster points to nodes of BSP-Tree, and to determine next best insertion

Efficiency

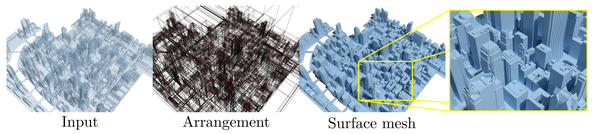


- Our method is at least one order of magnitude more time and memory efficient compared to previous plane arrangement methods on large-scale problems

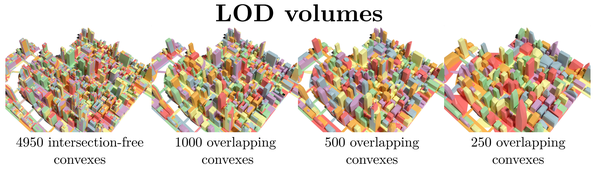
Surface simplification



Surface reconstruction



LOD volumes



Editable volumes