Reconstructing Complex Indoor Environments with Arbitrary Wall Orientations

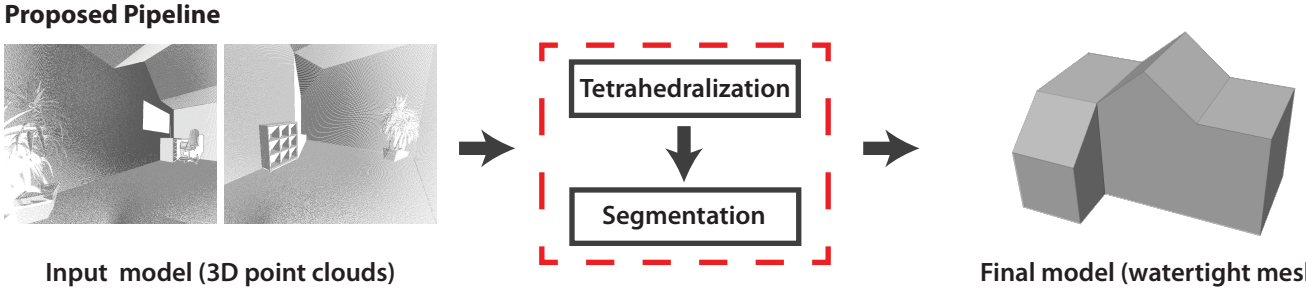
Claudio Mura *Oliver Mattausch* *Renato Pajarola* *Alberto Jaspe* *Enrico Gobbetti*

University of Zurich[UZH] VISUALIZATION AND MULTIMEDIA LAB CRS4 IDEAS BECOME LIFE

Introduction

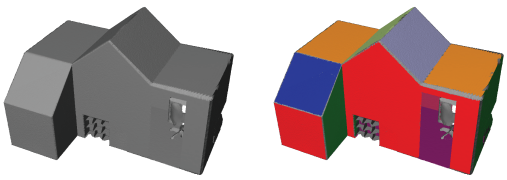
We present a pipeline for reconstructing a 3D model representing the architecture of an indoor environment from a set of point clouds obtained by laser range scanning. Current approaches typically make restrictive assumptions (e.g. *Manhattan-world* property) on the type of environments considered. To avoid such limitations, we represent the input scene as a tetrahedral complex, whose facets can adhere to wall structures with arbitrary orientations. The final model is obtained by applying a heat diffusion process to the complex, using a formulation that accounts for clutter and occlusions in the input data.

Proposed Pipeline



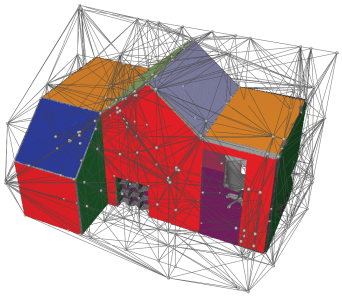
Tetrahedralization

We partition the space surrounding the input scene using tetrahedral cells, following the approach in [1]. We first detect planar patches in the input point clouds, then we cluster them using *mean-shift* to find a set of *dominant planes*. The intersections of such planes are used to compute a Constrained Delaunay Tetrahedralization (CDT), recently proposed in [3] for the reconstruction of urban scenes.



The input point clouds (left) and the results of the clustering of the detected planar patches (right, where each color represents a different orientation).

A *constrained* tetrahedralization is used to ensure that the wall structures (that must lie on the dominant planes) are represented by facets of some tetrahedra. To obtain the contraint triangles, we consider for each dominant plane the intersection points that lie on it and compute their triangulation on the plane itelf.



The tetrahedral space partitioning superimposed on the model. The grey spheres correspond to the intersections of the dominant planes.

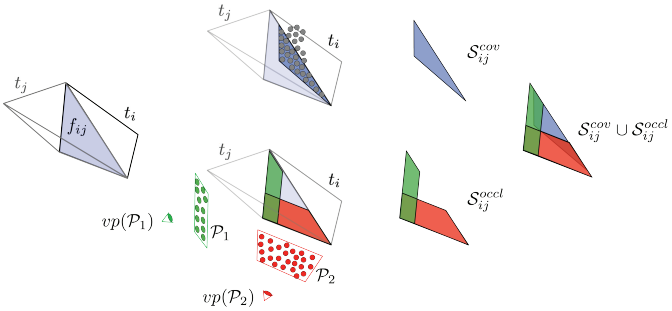
Segmentation

To obtain the final model, we apply a heat diffusion process to the dual of the complex and use a recursive binary clustering to extract groups of tetrahedra corresponding to individual rooms, as described in [2].

We define the diffusion matrix $\mathbf{D}$ in the following way:

$$\mathbf{D}_{ij} = \begin{cases} e^{-s_{ij}/2\sigma} & \text{if } i \neq j \ \wedge \ t_i, t_j \text{ adjacent} \\ 1 & \text{if } i = j \\ 0 & \text{otherwise} \end{cases} \qquad s_{ij} = \frac{\text{area}\,(\mathcal{S}_{ij}^{cov} \cup \mathcal{S}_{ij}^{occl})}{\text{area}\,(f_{ij})}$$

where t_i and t_j are two generic tetrahedra and f_{ij} is the triangular facet between them. The definition of s_{ij} accounts both for the surface $\mathcal{S}_{ij}^{cov}$ of f_{ij} directly covered by scanned points and for the surface $\mathcal{S}_{ij}^{occl}$ occluded by each planar patch $\mathcal{P}$, as seen from the point $vp(\mathcal{P})$ from which it was scanned.



Note that s_{ij} can be computed efficiently using the standard rasterization pipeline. In this setting, a per-pixel weight can be included to give more importance to the covered surface and to account for the distance from an occluding patch to the facet.

This formulation prevents heat from flowing across facets that are likely to lie on wall structures. This way, heat can propagate more quickly among tetrahedra that belong to a same room of the environment. Groups of tetrahedra with coherent heat level can be then extracted by clustering.

References

[1] Lafarge F. , Alliez P. : Surface reconstruction through point set structuring. Computer Graphics Forum 32, 2 (2013), 225-234

[2] Mura C. , Mattausch O. , Jaspe A. V. , Gobbetti E. , Pajarola R. : Robust reconstruction of interior building structures with multiple rooms under clutter and occlusions. In Proceeding IEEE Conference on Computer-Aided Design and Computer Graphics (2013), pp. 52-59

[3] Van Kreveld M. , Van Lankveld T. , Veltkamp R. : Watertight scenes from urban lidar and planar surfaces. Computer Graphics Forum 32, 5 (2013), 217–228

Contact: { claudio | mattausch | pajarola }@ifi.uzh.ch { ajaspe | gobbetti }@crs4.it

WWW: http://www.ifi.uzh.ch/vmml.html http://www.crs4.it/vic www.diva-itn.eu