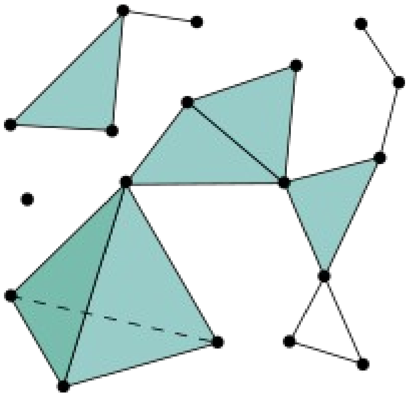
Simplicial Complexes Reconstruction



Simplicial Complexe in dimention 3 (source : Wikipedia)

1. Topic

Surface reconstruction is a widely studied geometry processing topic. It aims, from an input 3D point cloud, to extract the continuous surface of the underlying scanned objects. The probelm is ill posed and its resolution depends on numerous a priori on the caracteristics of the scanner (noise level, outliers,…), the scanning geometry (density and anisotropy of the sampling, occlusions), the properties of the scanned surface itself (regularity, symmetries, repetitions, holes, …) and the expected properties of the output (surface passing exactly through input points, preservation of discontinuities, watertightness), as detailed in [Berger et.al. 2014].
The main goal of this thesis is to reconstruct not a triangulated surface from the scene but a richer representation that may contain triangles but also edges and points, denoted by the general term simplices (span of n<d+1 points in dimention d). Such a mathematical object is called a simplicial complexe. This idea is motivated by the fact that at its sampling resolution, a real surface might not always be represented by a 2D interface separating volumes permeable or not to light. For instance, in urban areas, wires, barriers, chains,… may appear locally as linear (the point cloud is locally a set of nearly aligned points). The foliage of a tree will appear as a set of unorganised points where reconstructing a regular surface is meaningless as the details of branches and leaves are much finer than the point density. Beyond reconstruction of such simplicial complexes, the goal of this PhD is to adapt to simplicial complexes the geometry processing tools for surface mesh such as decimation, segmentation and texturing.

These tools should integrate naturally in the image and lidar processing chain, in particular for the production of structured and semantised data as described in [Vallet et.al. 2015] as these tools aim at producing a faithful continuous representation of reality from a discrete sampling.

2. Context

3D modeling of reality is mandatory for numerous applications (simulations, visualization, ...) IGN aims at producing an accurate and faithful 3D model of the entire french territory. The level of detail of such models depends on the sensor resolution and distance to the scene. On dense urban cores, urban planners and gestionnaries aim for a subdecimetric level of detail and accuracy, which can only be obtained by having the sensor very close to the scene (on a drone or terrestrial vehicle). This need triggered the development of the mobile mapping technology where the sensors are embarked on a truck or a car. However, processing such data faces some major challenges:

- Complexity : having the sensor within the image scene calls for true 3D processing to handle occlusions, radiometric issues, and the high heterogeneity and anisotropy of the sampling.
- Volume : mobile mapping produces roughly 1terabyto of data per vehicle and per day. It imposes proper computing and storage infrastructures, but also efficient, robust and automatized processing tools that scale up well.

Among such processing tools, surface reconstruction plays a central rôle at it converts a discrete sampling (pixels, 3D points) of a surface into a continuous representation (surface mesh). It is also very sensible to the challenges listed above. In the domain of photogrammetry and remote sensing, the surface reconstruction problem was mainly solved in 2.5D by producing Digital Elevation Models sampling a z=f(x,y) surface by storing a z value per pixel of an horizontal image defined in terrain coordinates. This approach produces surfaces with a homogeneous level of detail (the pixel size) and scale well by tiling the area of interest. For mobile mapping, such an approach is only possible for very specific obecjts such as façades[Demantké et.al. 2013] and road surface [Vallet and Papelard 2015] and needs to be replaced by true 3D surface mesh reconstruction for more generality [Caraffa et. al. 15], which is more complexe but also more flexible. However, because of the application of the Nyquist-Shannon theorem to geometric sampling, if the geometric level of detail is higher than the sampling resolution, this level of detail is lost by sampling. A surprising consequence is that the apparent dimentionality of the surface might change : a pole with diameter below the sampling resolution will appear linear, the scan of tree foliage will appear as an unstructured point set without any linear or surfacic trend. In the linear case, most surface mesh reconstruction approaches will fail, generate very elongated triangles or no triangle at all. In the second case, the result is a very random connection of the points with no connection with the physical reality. For these reasons, we propose to take explicitly this local dimentionality into account in the structure of the reconstructed object, which becomes a simplicial complexe.

3. Goals and detailed program

The PhD will have 3 parts: (i) analysis of the state of the art in surface reconstruction from point clouds, based on [Berger et.al. 2014] for instance; (ii) generalisation to simplicial complexes of the most adapted method ; (iii) generalisation to simplicial complexes of 3D surface mesh processing tools.

The state of the art should be conducted with two major objectives in mind:

- Adaptability to the context of complex and big mobile mapping data.
- Facility of generalization to simplicial complexes.

We will not impose watertightness to the resulting surface as most watertight methods are based on extracting a (dimention 2) isocontour from a function defined in space. Delaunay based methods will probably be the most appropriate as a simplicial complexe can be defined as a subset of a 3D Delaunay triangulation of the points. The estimation of complexe dimentionality could rely on an estimation of the dimentionality based on the point could as done in [Demantké et.al. 2011].
For processing, decimation will be the main target as it is very tightly connected to reconstruction. For that purpose, the PhD candidate will investigate existing point cloud and surface mesh decimation techniques and propose a more general method exploiting their synergies to decimate simplicial complexes.

Concerning segmentation, the same approach can be considered, as point cloud and surface mesh segmentation are well studied problems.

4. Data

The method will be developped for mobile laser scanning, but should be applicable to any point cloud exhibiting structures of various dimentionality. For mobile laser scanning, the MATIS Lab has more than 100TBytes of data covering the integrality of Paris and a few other major french cities, which is more than enough to validate how well the developped methodologies scale up and their robustness to variability in scene typology.

5. Direction

This thesis will be located in the MATIS lab (IGN France) and directed by Bruno Vallet. Loïc Landrieu will be the main advisor. Bruno Vallet leads the MATIS lab reserch on image and lidar data processing from calibration and registration to 3D modelization and semantisation, with a strong focus on mobile mapping data. Loïc Landrieu is a MATIS researcher specializing in structured and semantized surface reconstruction, and in particular on segmentation, generalization and optimization which were the topics of his PhD thesis.

6. Keywords

Classification, Machine learning, computer vision, laser scanning.

7. Technical Environnement

For practical reasons, the PhD work will be conducted in C++ under Ubuntu.

8. Requirements

- Masters degree in computer vision, machine learning or image (or geometry, or signal) processing.
- Strong experience in C++ development
- Autonomy, pragmatism
- Strong interest in scientific research

8. Conditions

- The position will be for 3 years, and will start between september and december 2016.
- Localisation : Laboratoire MATIS - Institut Géographique National, 73 avenue de Paris 94165 Saint Mandé, France
- The wages will be 2000-2300€ per month depending on the experience of the candidate.

9. Contacts

Applications consist of a cover letter describing how your research experience is relevant to the position and a resume sent to both advisors. You can also contact both advisors for more information about any aspect of the position and research topic :

- Bruno VALLET, Phone : 01 43 98 80 81, Mail : bruno.vallet@ign.fr
- Loïc LANDRIEU, Mail : loic.landrieu@ign.fr

10. References

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