1.1 LiDAR point clouds

- Active acquisition method
- Fixed, embarked, aerial
- High precision (<1cm)
- Huge volume (>10^7)
- Complex structure

Goal: semantic classification and segmentation

1.2 Graph structure of point clouds

- Graph structure $G = (V, E, w)$
- $V$: set of 3D points
- $E$: adjacency relationship
- $w$: edge weight or features
- $k$-nn, Voronoi adjacency, etc...

1.3 Graph-structured optimization

$$x^* = \arg \min_{x \in \Omega} \sum_{v \in V} f(x_v, y_v) + \sum_{(u,v) \in E} g(x_u - x_v)$$

- Piecewise constant approximation of a function on a graph:
  - $\Omega$ search space
  - $y$ observation/features
  - $f$ fidelity function
  - $g$ sparsity inducing
- Fast solving algorithms depending on the nature of $\Omega$, $f$ and $g$:
  - Combinatorial: $\alpha$-expansion
  - Continuous + convex: PFDR
  - Continuous + non-convex: $\ell_0$-cut pursuit [1]

2.1 Probabilistic classification

- Numerous methods exists for classifying 3D points
- Produces a probabilistic classification $y$ on each vertex
- Allows to compute the certainty of each affectation
- No spatial regularity

2.2 Spatial regularization

- State-of-the-art: CRF structured by $G$: $\Omega = S$ corners of the simplex, $f(x_v, y_v) = \langle x, \log(y_v) \rangle$ and $g = \delta(\cdot \neq 0)$
- MAP inference: fast but produce a hard labeling
- Marginal inference: slow and poor precision
- Structured regularization [2]:
  - Relax $\Omega$ to the full simplex
  - Generalize $f$ to $\|x_v - y_v\|$, $\text{KL}(x_v, y_v)$, $(x_v, y_v)$ and $g$ to $\cdot$

2.3 Regularization results

pointwise classification associated certainty

3.1 Geometric segmentation

- Geometrically simple $\Rightarrow$ semantically homogeneous
- Piecewise constant approximation of geometric features: $f(x_v, y_v) = \|x_v - y_v\|^2$ and $g = \delta(\cdot \neq 0)$
- Can efficiently be solved by cut-pursuit
- Evaluating the segmentation: purity of the segment w.r.t a ground truth

3.2 Segmentation results

- Probabilistic classification associated certainty

References
