Individual Tree Mapping from LiDAR point clouds based on topological tools

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Mapping individual tree structures from a LiDAR point cloud

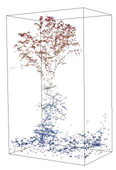
- Problems
  - Forest understructure
  - Partial occlusions
  - Noise
- Methods focusing on geometry fit well on specific types of trees only

Proposed approach

1. Input – point cloud
2. Infer a topology to the point cloud by means of a VR complex
3. Compute a morphological representation by means of a Forman gradient
4. Simplify the Forman gradient for identifying relevant features

Vietoris Rips (VR) complex

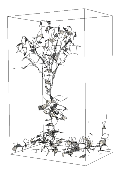
- A VR complex is a simplicial complex obtained by connecting with an edge all the points closer than a specific distance and by computing the maximal cliques or the resulting 1-skeleton.



Input Point cloud

- Objective – infer a topology to the point cloud

- After creating the 1-skeleton from the point cloud we compute the cliques limiting their expansion to dimension three. (i.e., our simplicial complex will be composed by vertices, edges, triangles and tetrahedra)



VR complex

Discrete Morse Theory [Forman 1997]

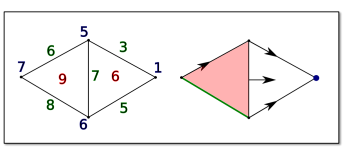
- Let Σ a simplicial complex and F a scalar function defined on its simplices.

- F is a Forman function if, for every i-simplex σ of Σ:
  - all the (i-1)-simplices τ, faces of σ, $F(\tau) < F(\sigma)$, and
  - all the (i+1)-simplices δ, cofaces of σ, $F(\delta) > F(\sigma)$

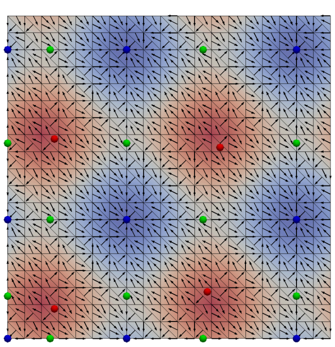
  with at most one exception. Such exception defines a *gradient pair*. If there is no exception σ is a *critical simplex*

- *V-path*, is a sequence of simplices $[\sigma_0, \tau_0, \sigma_1, \tau_1, \ldots, \sigma_n, \tau_n]$ such that:
  - σ_i and σ_{i+1} are faces of τ_i, and
  - (σ_i, τ_i) are gradient pairs.

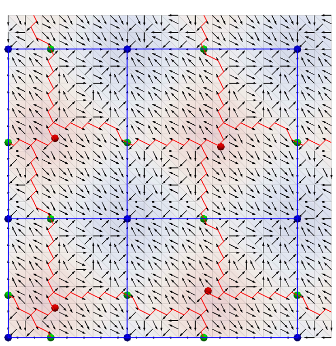
- The collection of all the gradient pairs V is a *Forman gradient* if all the V-paths are acyclic.



- Starting from a scalar function defined on the vertices of Σ (i.e., the height function) we compute a Forman gradient by extending F to the remaining simplices.



Forman gradient



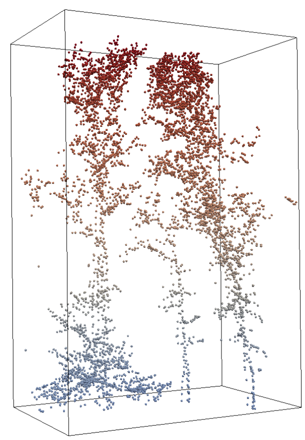
Combinatorial structure extracted from the Forman gradient

Topological features and simplification

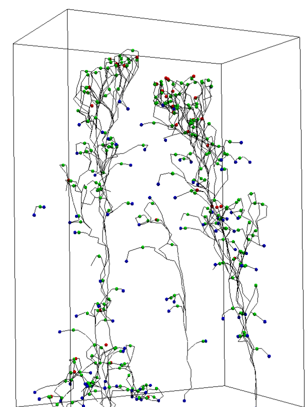
- The Forman gradient provides a combinatorial representation for studying the evolution of the VR complex.
- Critical simplices identify the topological features of our dataset.

  Minimum – point where the trunk connects to the ground
  Saddle – point where a branch connects with the tree or two crowns overlap
  Maximum – heights point reached by a tree

- By applying persistence based simplifications [Edelsbrunner et al. 2002] we remove the low level features (pair of critical points close in terms of function values) keeping only higher level features.



Input Point cloud



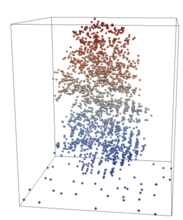
Simplified 1-skeleton extracted from the Forman gradient

Results

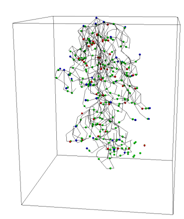
- The proposed approach has been tested on a broadleaf dominated experimental forest in Maryland managed by the Smithsonian Environmental Research Center (http://www.sigeo.si.edu).

- Our preliminary implementation works on different subsets of the dataset independently. Approximately 90% of the trees are correctly split.

- The approach can be generalized to other types of forest by modifying the function values to find the most characteristics features.



Input Point cloud



1-skeleton obtained filtering the VR complex from top

Acknowledgement

- We thank Professor Ralph Dubayah, Laura Duncanson, Steven Hancock and John Armston for their help and valuable comments
- This work has been partially supported by the US National Science Foundation under grant number IIS-1116747