Power lines Extraction from LiDAR Based on Hough Transform and RANSAC

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Summary

Filter points by the labels of ASPRS

Project points on XOY plain

Further filter point by GMM

Rasterization with cell size = 1

Buffer operation

Construct corridors

dysconnectivity

Hough transform

RANSAC
### ASPRS Standard LIDAR Point Classes

<table>
<thead>
<tr>
<th>Classification Value (bits 0:4)</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Created, never classified</td>
</tr>
<tr>
<td>1</td>
<td>Unclassified$^1$</td>
</tr>
<tr>
<td>2</td>
<td>Ground</td>
</tr>
<tr>
<td>3</td>
<td>Low Vegetation</td>
</tr>
<tr>
<td>4</td>
<td>Medium Vegetation</td>
</tr>
<tr>
<td>5</td>
<td>High Vegetation</td>
</tr>
<tr>
<td>6</td>
<td>Building</td>
</tr>
<tr>
<td>7</td>
<td>Low Point (noise)</td>
</tr>
<tr>
<td>8</td>
<td>Model Key-point (mass point)</td>
</tr>
<tr>
<td>9</td>
<td>Water</td>
</tr>
<tr>
<td>10</td>
<td>Reserved for ASPRS Definition</td>
</tr>
<tr>
<td>11</td>
<td>Reserved for ASPRS Definition</td>
</tr>
<tr>
<td>12</td>
<td>Overlap Points$^2$</td>
</tr>
<tr>
<td>13-31</td>
<td>Reserved for ASPRS Definition</td>
</tr>
</tbody>
</table>
1. Filter non-line points based on the labels from ASPRS

Original LiDAR Data

LiDAR Data via filtering
Remaining points after filtering ground, high vegetation and key points

A big challenge is to detect the lines in the area labeled by red ellipse.
2. Use GMM to further filter non-line points

I project the remaining LiDAR points on the plain of XOY as shown the left figure. Please notice the area labeled by red circle. The density of the points is very high so as to have negative effect on detecting lines using Hough Transform, which is the main reason to do further filtering non-line points. At the same time, filtering more non-line points is equal to reducing computing consumption.
2. Use GMM to further filter non-line points

According to the character of a line, a cylinder is used to fit a point and its \( n \) nearest points, and if the point is on a line, the cylinder will have a longer axis.

1. Use cylinder fitting model to generate a cylinder for each point and its \( n \) nearest points.
2. Use PCA (Principal Component Analysis) to obtain the three vectors that reflect main data changing trends.
3. Transform the problem of filtering noise points to a binary classification problem so that I can use unsupervised learning model to solve it.
After filtering by GMM

Before filtering by GMM
3. Generate a raster image based on the remain points

Project the points to the plain XOY and transform them to a raster image based on the cell size = 1. The result is shown in the following figure. The reason is that it is possible for me to create less corridors and detect more powerlines because multiple lines will overlap to one line when they are projected into the plain XOY.
4. Use Hough Transform to detect lines in a raster image
Filter the lines with bad dysconnectivity

Evaluate the extent of dysconnectivity of each line and in this project, if the length of the continuous discontinuity of a line exceeds 20 cells, it will not be regarded as a powerline. Based on the threshold, the lines detected by Hough Transform can be further filtered and the result is as shown in the right figure.
5. Construct Corridors of Power Lines by Buffer Operation

On the basis of the lines detected from the raster image, I did a buffer operation with the width of 4m along the lines to set up the corridors of power lines.
When finishing the construction of corridors, it is easy to use them to locate the points of power lines. However, some non-line points over or below lines are also found as shown in the right figure.
6. Use Corridors to Locate the Points of Power Lines

How do I separate the non-line points from the lines? I project the points into the plain YOZ as shown in the right figure. This problem can be transformed to a binary classification problem. There are some unsupervised machine learning models to be able to solve this problem. Here what I selected is **RANSAC** because it has better efficiency and ability to resist the influence of outliers.
Use RANSAC to filter non-line points
Similarly, I do the same operations on each powerline corridor and can get all points of powerlines finally as shown in the following figure.
Synopsis

1. Simply filtering non-line points based on the labels defined by ASPRS.
2. Using cylinder fitting and Gaussian Mixture Model (GMM) to further filter non-line points.
3. Generate a raster image based on the remain points after two filtering.
4. Detect lines from the raster image based on Hough Transform.
5. Construct powerline corridors via doing Buffer operation on the lines of a raster image.
6. Locate the accurate positions of power lines according to the corridors and RANSAC (Random Sample Consensus).