

# Tutorial: Using LiDAR Data for Power Line Corridor Management

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## Introduction

Routine inspection of power line corridor is critical for securing uninterrupted distribution of electricity. Traditional ground-based inspection methods, such as calculating the distance between the sag of the transmission wires and underlying vegetation using height measuring rods and theodolites, are labor-intensive, time-consuming, risky for field staffs, and insufficient in accuracy.

Recently, LiDAR technology has been utilized to improve the efficiency and effectiveness of power line corridor management. GreenValley International (GVI) provides a total solution of acquiring point cloud dataset of power line corridor using aerial and ground LiDAR system, and processing point cloud dataset using software designed for utility industry to inform decision-making in power line corridor management.

This tutorial provides an intuitive and time-efficient workflow to process the point cloud dataset, collected using GVI's LiAir UAV LiDAR System, with GVI's LiPowerline software to build 3D models for utility infrastructures, identify vegetation encroachments, simulate wire conditions under certain weather scenarios, predict tree fall hazards, and model vegetation growth pattern to predict potential hazard. This workflow has been used in many utility companies to upgrade their vegetation management solution.

Please follow the instructions in the tutorial to install LiPowerline software, download sample data, and complete the exercises with the sample data. It is recommended that you go through the entire tutorial to learn the concepts and tools, and then adopt it in daily workflow of your own organization and projects. However, with prerequisite sample data prepared for you in each exercise, you could start at any exercise in this tutorial to learn a specific workflow.

## Software requirement

Please download the latest version of LiPowerline from the [GreenValley International official website](#), and install and activate following the User Guide.

## Sample data

The [SampleData.zip](#) folder provides sample datasets for the following exercise. Please unzip the compressed folder.


## Exercise 1: Power line corridor modeling

3D models of power line infrastructures are important data asset for power line corridor management. Informed by accurate location information and high spatial resolution, decisions in design and planning, management, and maintenance can be made with less uncertainties. LiPowerline utilizes machines learning algorithms to automatically classify power lines and towers, ground, and other objects, which significantly advances the modeling process.

Use the dataset in Exercise1 folder as input data for this exercise.

### Classifying power lines and towers using Machine Learning

#### 1 Load data

- 1.1 Launch **LiPowerline**  software as Administrator.
- 1.2 Click **File > Data > Add Data**, browse to the downloaded PowerlineSample.LiData dataset, and **Open**. The point cloud dataset is added automatically to the PointClouds Layers group in **Project Management** Window, and the **Power Line Parameter Setting** window opens automatically.

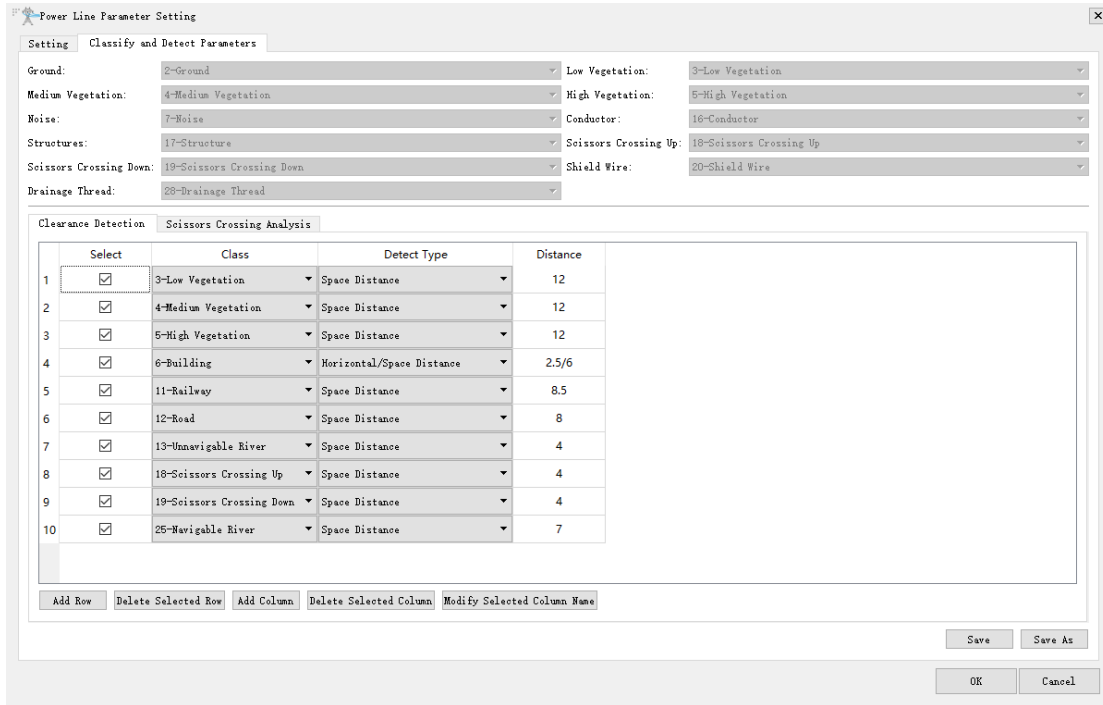
LiPowerline supports .las and .LiData. If .LAS file is opened, the **Open LAS File** window is opened for initial properties set up.

- 1.3 In the **Power Line Parameter Setting** window, under the **Setting** tab, set **Working Directory** to your working folder.
- 1.4 For **Classify and Detect Parameters**, please select 'Sample.xml' file in the software installation folder, for example: *C:\Program Files\LiDAR360Suite\LiPowerline\Sample.xml*. Parameters set up in **Clearance Detection** are used to determine whether an object should be classified as dangerous points in the **Danger Point Detection** analysis in Exercise 2.
  - 1.4.1 For **Detected Line Voltage Level**, select 220kV.
  - 1.4.2 Click **Classify and Detect Parameters** tab. Notice that the parameters have been populated using values set in the Sample.xml configuration file. Customize the parameters for this project:

1.4.2.1 Ground clearance is not within consideration in this project.

Therefore, select the first row, and click **Delete Selected Row**.

1.4.2.2 Change detection distance for Class 3-Low Vegetation, 4-Medium Vegetation, 5-High Vegetation to **12** meters, meaning that vegetation within 12 meters of power lines violates clearance distance.



1.4.2.3 Click **Save As** > save the file as config.xml file in the working directory.

In your own project, if the default classification schema is different from the schema your organization uses, you can customize the schema:

1. Click **Display** on LiPowerline toolbar > **Class Setting Options**.
2. Class **0 – Never Classified, 1 - Unclassified, 2 - Ground** are fixed classes that cannot be changed. Other than these classes, double-click on the name of the class and type in the new name.


If you don't have a configuration file for your project, you can create one in the **Classify and Detect Parameters** window:

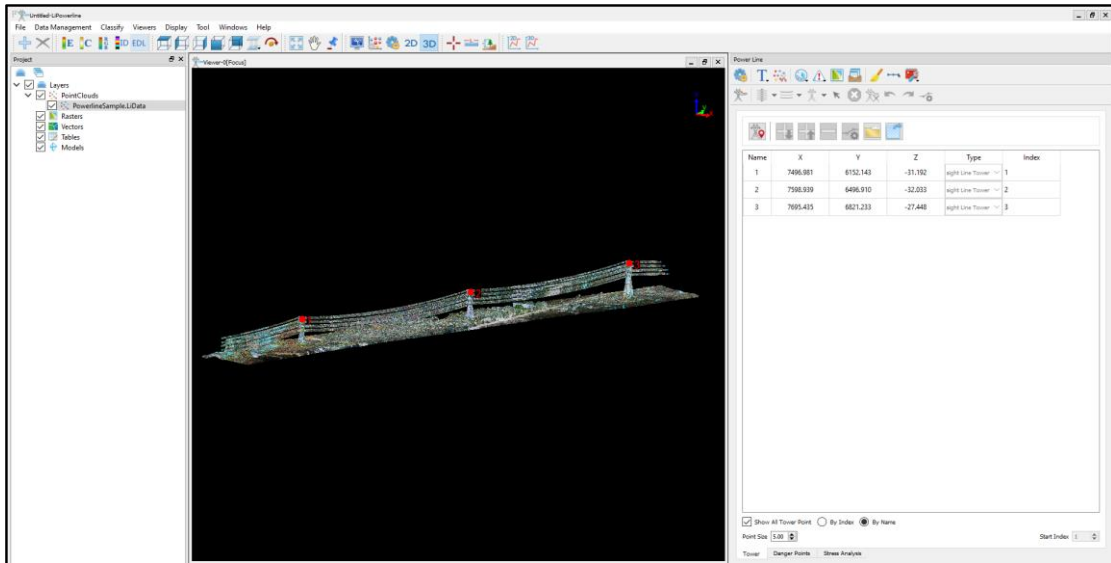
1. Select a **Detected Line Voltage Level**.
2. After adding a new voltage level in the **Setting** window, you can set its corresponding detection parameters for clearance violation detection and scissors crossing analysis in the **Classify and Detect Parameters** window. Click on the **Classify and Detect Parameters** tab, and click on **Clearance Detection** tab.
3. Click **Save** to save the parameters as a config.xml file for future reuse.


## 2 Mark the towers


The locations of power tower can be marked manually on the map, or by importing vector files (.LiTower, .kml, .txt, .csv). To mark towers on the map:

- 2.1 In the **Power Line** panel, click **Mark Tower**  to start editing towers.

- 2.2 Click **Add Tower Backward** , on the point cloud map view, left-click on the top center of power towers sequentially to add location of all towers along the power line. For each tower, change its type to Tension Tower or Straight Line Tower. In this project, all three towers are **Straight Line Tower**.



2.3 After finishing adding all tower locations, click **Mark Tower**  again to stop editing. The tower location file tower.LiTower is saved automatically to the working directory.

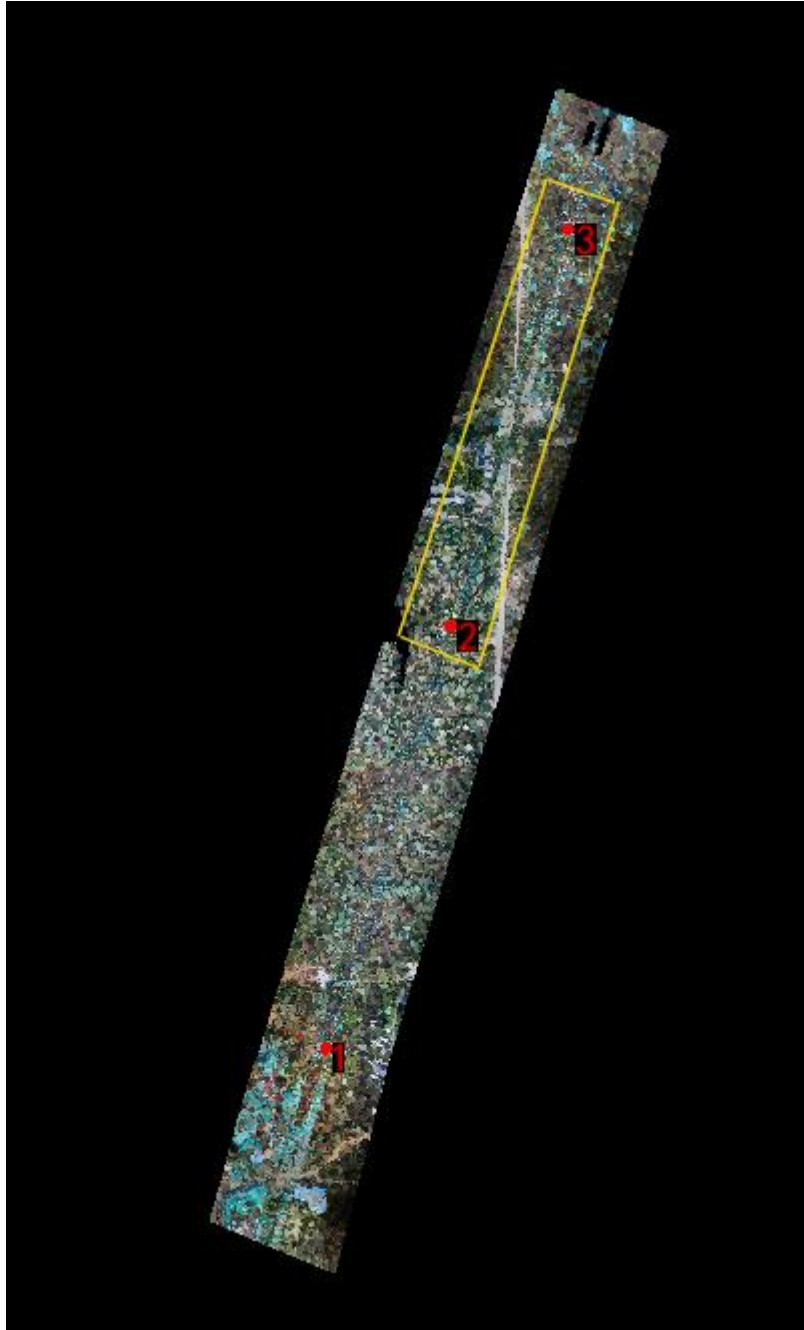
If vector file of tower locations exists, click **Import Tower File**  to import select and import the file. The format of .txt and .csv file should be as below with columns of Name, X, Y, Z, Type, Index. Type 'N' represents tension tower, and type 'Z' represents straight line tower.

```
Index, X, Y, Z, Type, Name
1, 7496.981000, 6152.143000, -31.192000, Z, 1
2, 7598.939000, 6496.910000, -32.033000, Z, 2
3, 7695.435000, 6821.233000, -27.448000, Z, 3
```

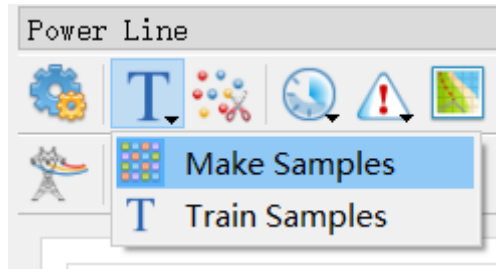
### 3 Generate training samples


The software applies machine learning method for automatic classification of power lines and power towers. Before automatic classification, users need to generate training samples of power line, tower, ground, and other classes manually for further use in machine learning. At least one full span (everything between two power towers) is required for training sample. Please follow these steps to generate training samples:

- 3.1 Identify one typical span of power line that is representative of the structures and environment in this project. In this exercise, we will use the span between tower 2 and tower 3:



- 3.2 Click **Train > Make Samples**:



3.3 In **Select Tools** bar that popped up, click **Polygon Selection** .


3.4 Click on the map to select the points in the span identified in Step a). Double-click to finish selecting. The selected points are highlighted:

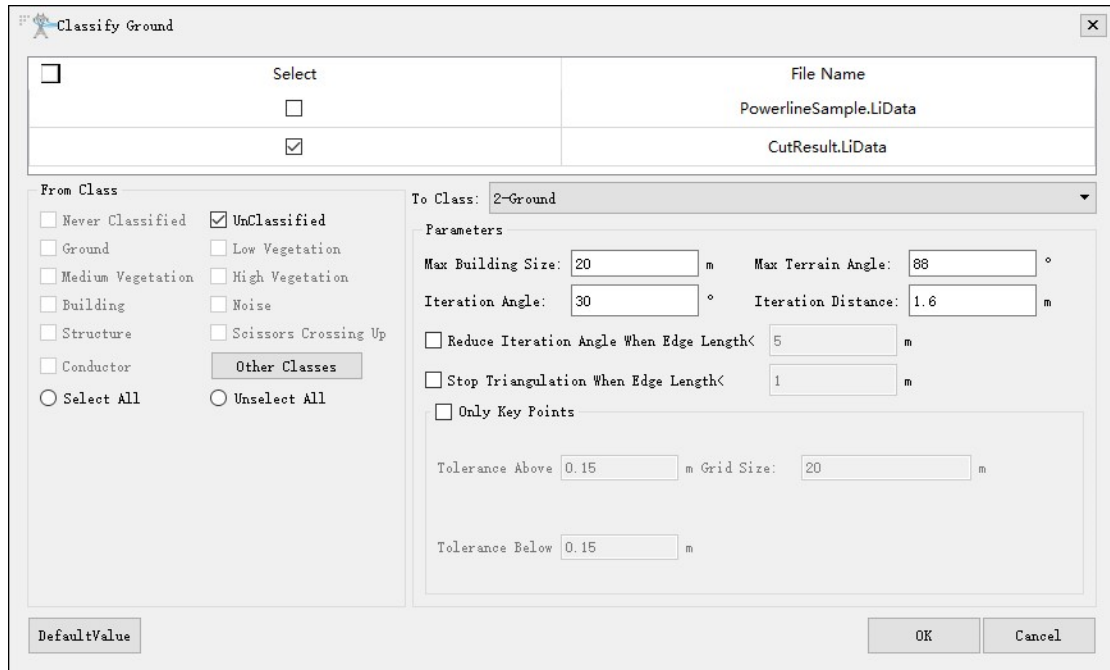





3.5 Click **In Cut**  to cut the point cloud:





- 3.6 Click **Save Cut**  , and change the output name to: CutResult.LiData. Click **Yes** in the ToolTip window to add the result to the view.
- 3.7 In the **Project** window, uncheck the PowerlineSample.LiData layer.
- 3.8 Classify the ground points: click **Classify** on top menu > **Classify Ground**. use the default parameter settings as below and click **OK** to run the tool.



3.9 Click **Display by Class** . The classified ground points are displayed in brown, and other unclassified points are classified in white.

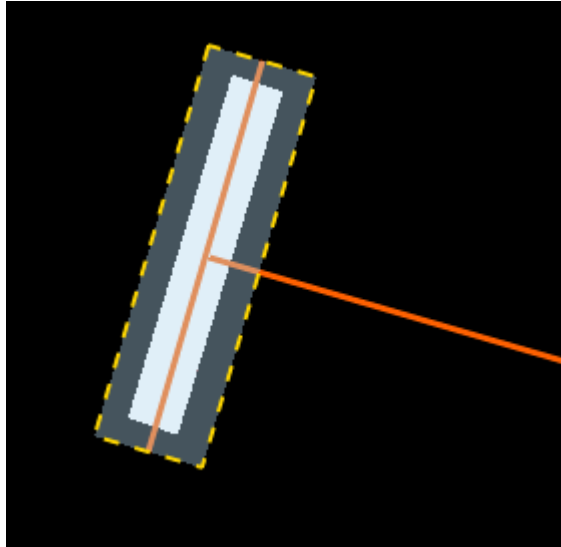
3.10 Right-click on the CutResult.LiData layer > **Zoom to Layer**.

3.11 Classifying the power lines and towers manually: LiPowerline provides two

manual classification mode: **2D Profile**  and **3D Profile** . In 2D Profile mode, user select and classify points in a manual define 2D profile view, while in 3D Profile mode, user can rotate the point cloud in a 3D view to select and classify points in a proper perspective. Follow these steps to classify points into power lines and towers:


3.11.1 Click **2D Profile** . A new **Profile** window and **Common Class Setting** panel appears.

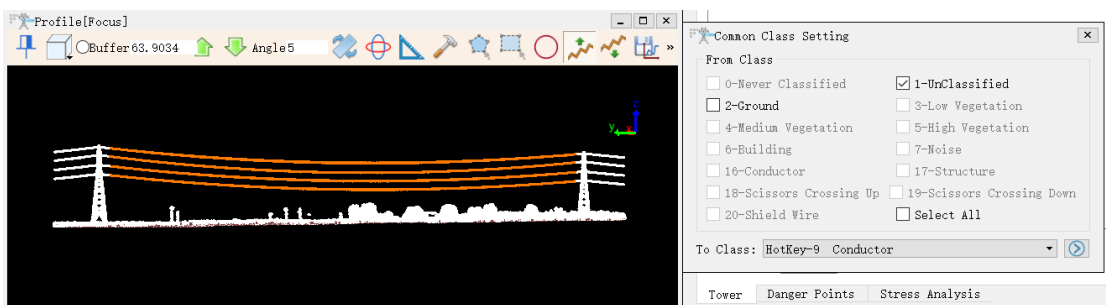
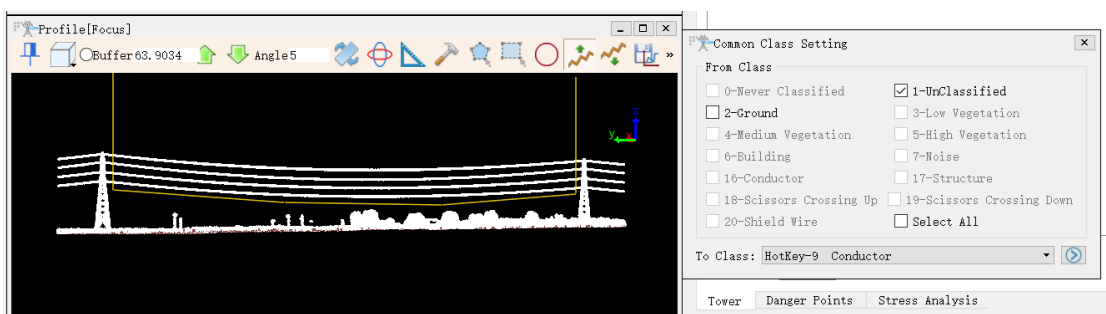
3.11.2 In the main Viewer window, single-click on outer side of the two towers to draw a line in the center along the power line span, and move the cursor up/down to adjust the buffer. Once all power lines in the span is included, double-click to finish defining the target area:



3.11.3 In the **Common Class Setting** panel, check ‘1-Unclassified’ as **From Class**, and select ‘Conductor’ as **To Class**.


In your own project, if the point cloud dataset has never been classified, the class for all points would be ‘0-Never Classified’. In that case, select ‘0-Never Classified’ as **From Class**.

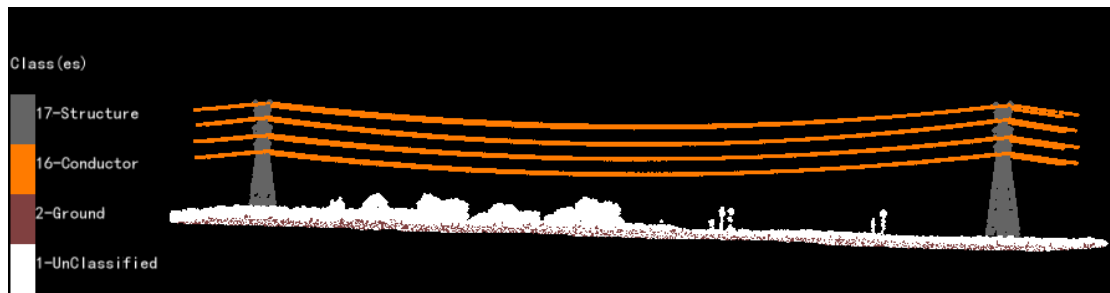
3.11.4 Use the Select tools  to select power lines in the Profile view. The points that are selected will be changed into a new color:



Since further edits will be made in the following steps, don't worry about selecting all power line points in this step.

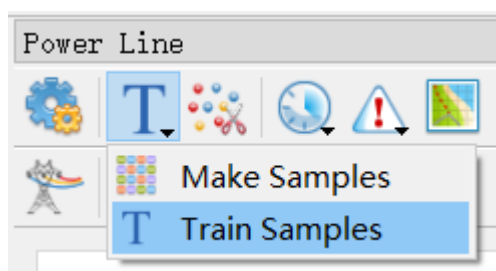
3.11.5 Click **Save Results**  to save the classification, and close the **2D Profile** view window.

3.11.6 Click **3D Profile**  to open the 3D Profile view. Move and rotate the point cloud in the 3D viewer, and use **Polyline Above Selection**, **Polyline Below Selection**, **Polygon Selection**, **Rectangle Selection**, and **Circle Selection** tools to select and classify the unclassified power line and power tower points. You may switch back and forward between the 2D Profile mode and 3D Profile mode to classify the points.



#### 4 Train the samples


4.1 In Power Line window, click **Train > Train Samples**:



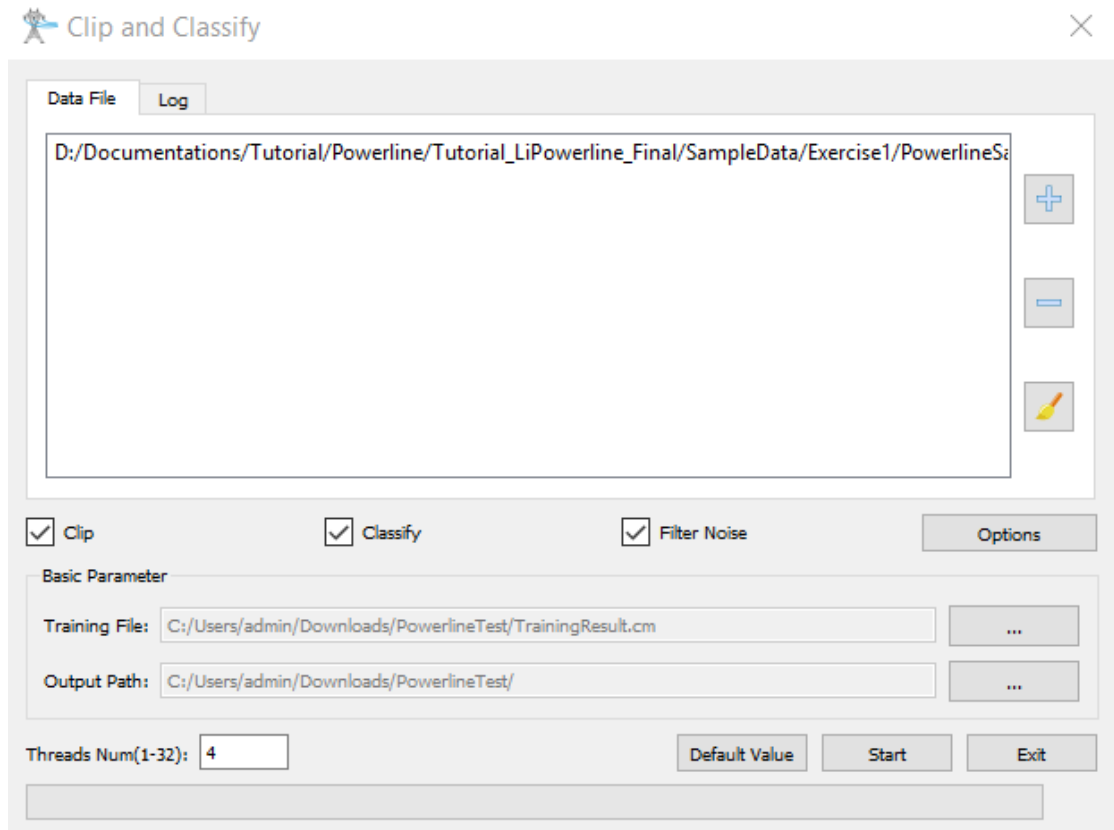
4.2 In the **Classify of Training** tool window, select CutResult.LiData as **Input Training File**, and remove PowerlineSample.LiData from **Input Training File** if it is listed, set output file as TrainingResult.cm in the working directory. Click **OK** to run the tool.

4.3 Remove the CutResult.LiData from Project.

#### 5 Clip and classify

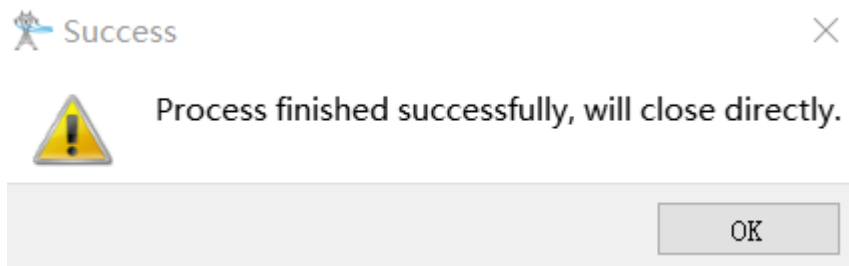
5.1 In Power Line window, click **Clip and Classify** .

5.2 In the **Clip and Classify** window, click **Options** to expand the **Advanced Parameters**. Adjust the parameters as needed. In this exercise, make sure the values are as below:



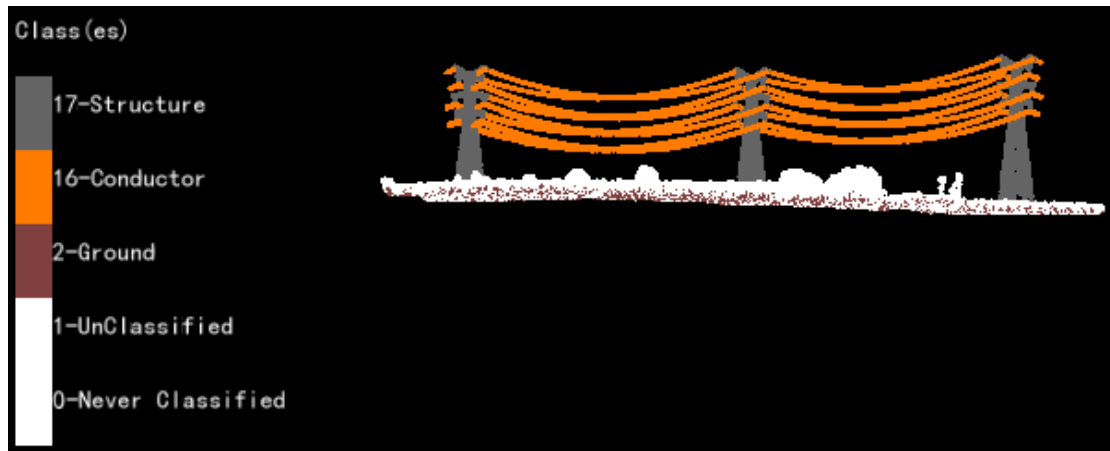
5.3 Click **Start** to start processing.

5.4 Click **OK** in the Success window when finished:



5.5 Add the clipped and classified point cloud datasets, 1-2(1\_2).LiData and 2-3(2\_3).LiData, to LiPowerline. Notice that power lines and power towers are now classified in different classes.

- 5.6 For the points classified incorrectly, use the 2D Profile and 3D Profile tools to manually reclassify them into correct classes.



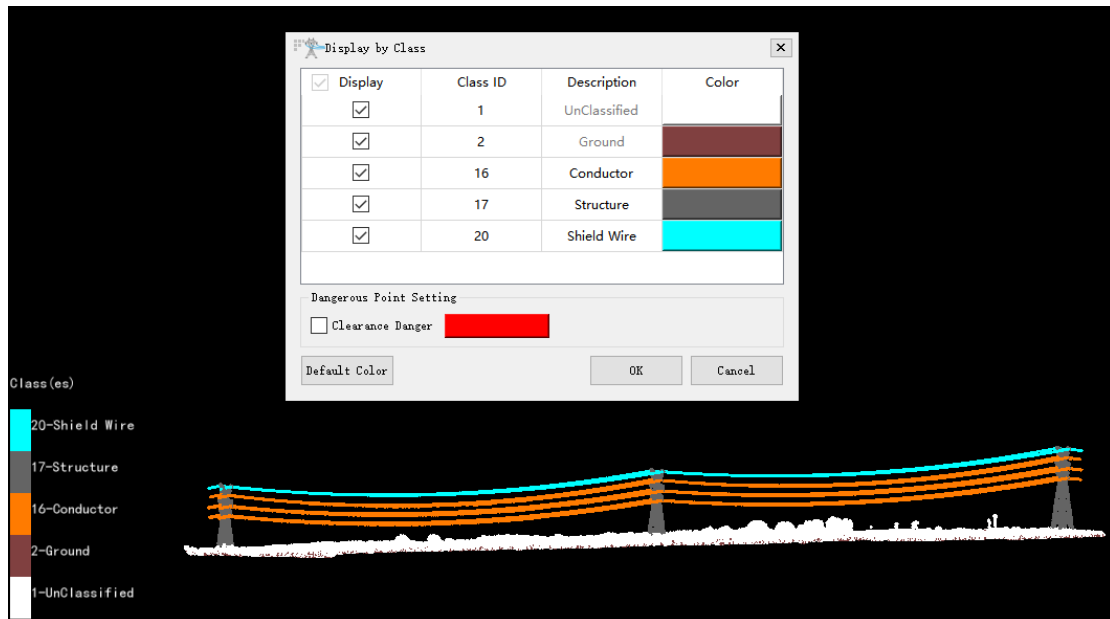
### Classifying shield wires and vegetation

Using Machine Learning, we have successfully classified the power towers and power lines. Above we classified the two shield wires on the top as ‘Conductor’. Next, we will reclassify them back to ‘Shield Wire’. Further, notice that the majority landscape is covered by low vegetation in this sample dataset, we will classify the landscape points into ‘Low Vegetation’.

#### 1 Classify shield wires

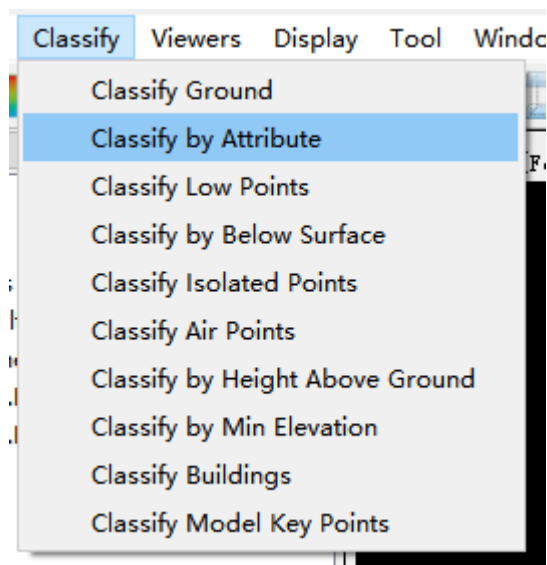
- 1.1 Use **2D Profile** or **3D Profile** tool to classify the two shield wires on the top from ‘Conductor’ to ‘Shield Wire’. Save the classification result.
- 1.2 The default display color for ‘Shield Wire’ is the same as ‘Conductor’.

Click **Display by Class**  in **Display** toolbar, and change the display color for ‘Shield Wire’ to blue:



## 2 Classify vegetation

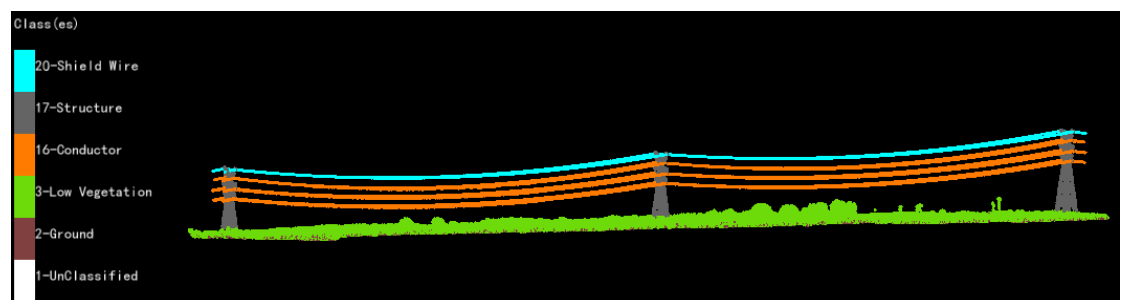
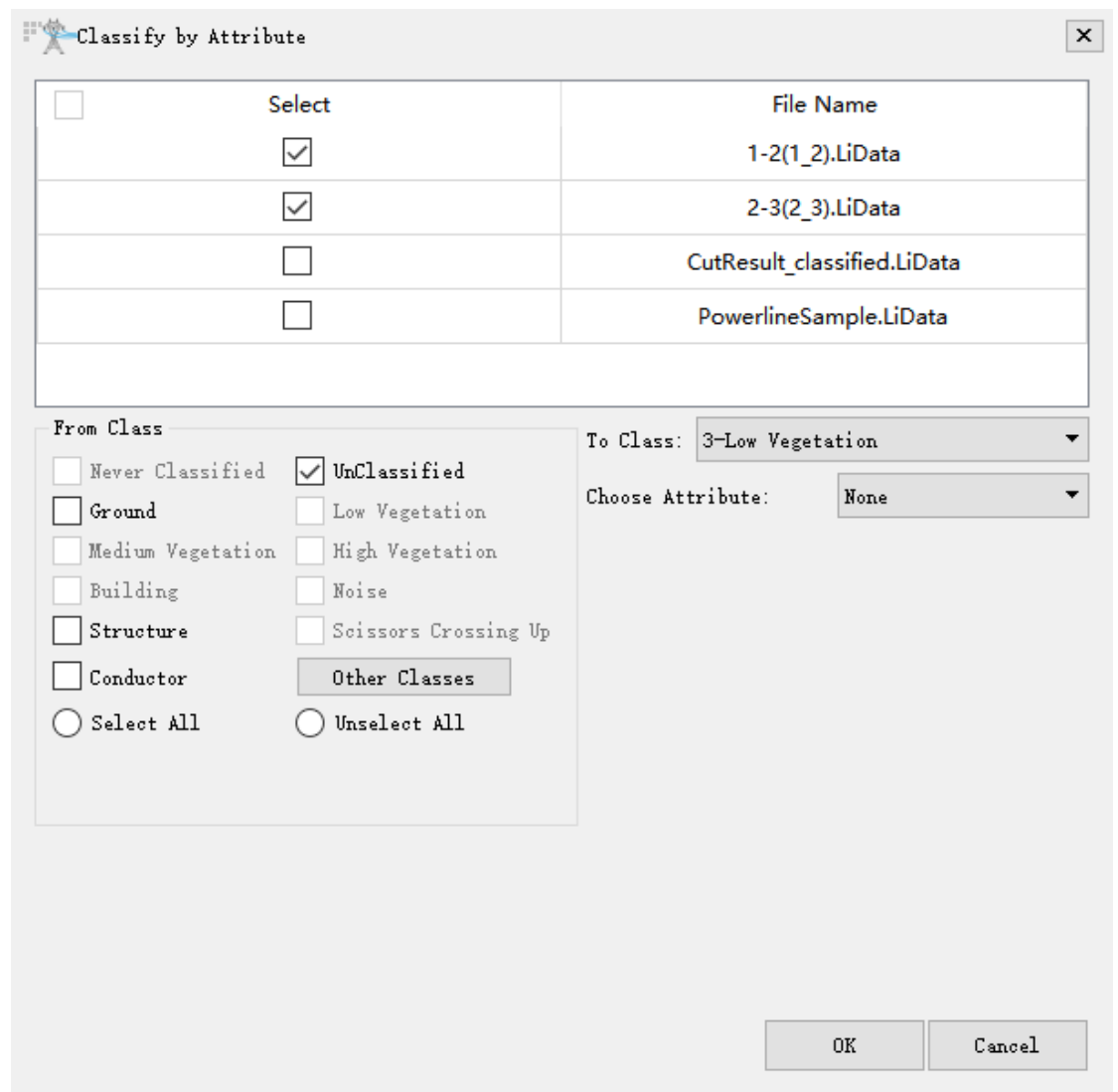
### 2.1 Click **Classify** in toolbar > **Classify by Attribute**:



### 2.2 For input dataset, select 1-2(1\_2).LiData and 2-3(2\_3).LiData; **From Class**: 'UnClassified'; **To Class**: '3-Low Vegetation'. Click **OK** to run the tool.







This process classifies all the unclassified points into 'Low Vegetation'.

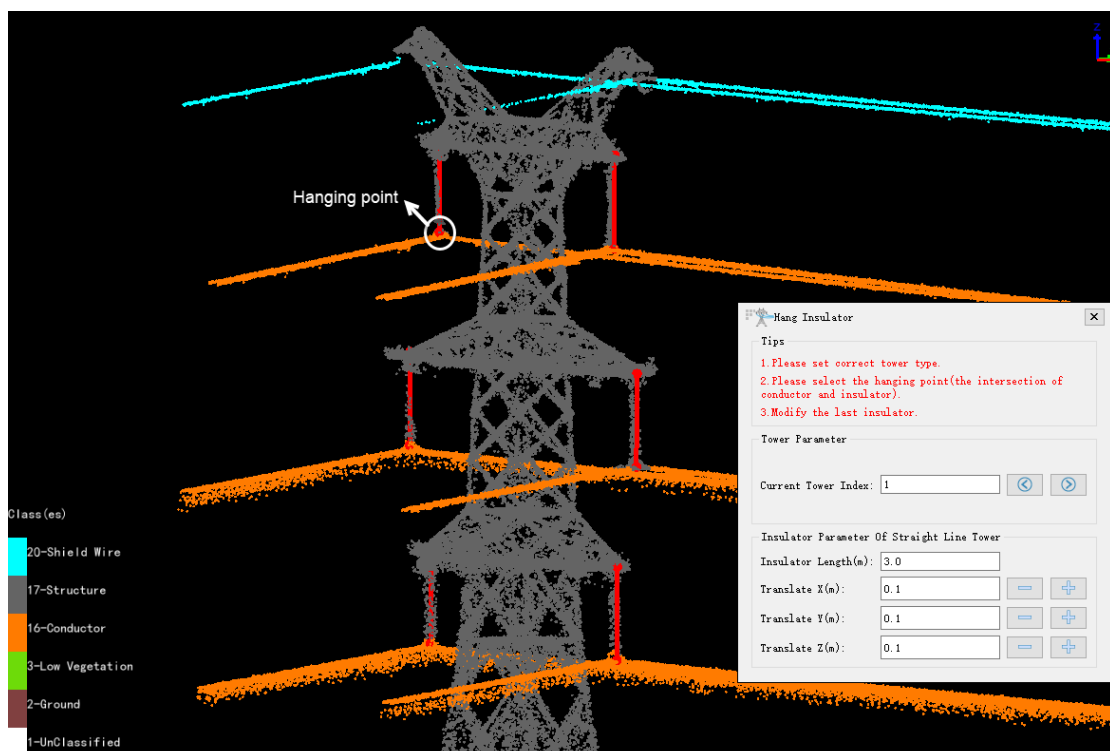


## Vectorizing power infrastructures

After classification, we will vectorize the insulators, power lines, and towers to generate complete power infrastructure objects, and export them as vector file (.shp) for further analysis.

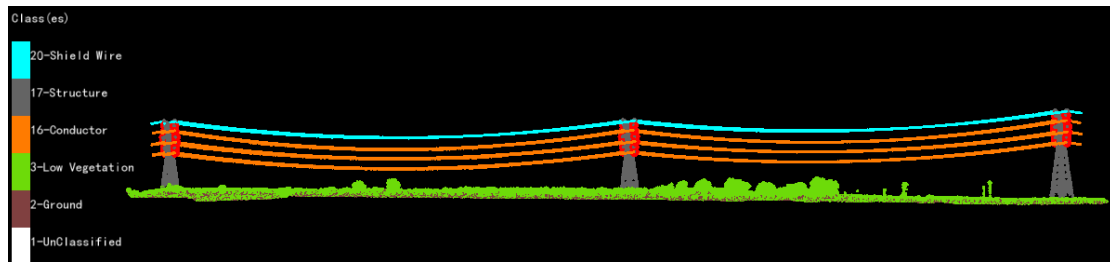
### 1 Vectorize insulators

- 1.1 Click **Vectorization Editing**  in the Power Line panel to activate the vectorization editing tools.
- 1.2 Click **Insulator Editing**  to open the insulator vectorization toolbar.
- 1.3 Click **Hang Insulator** . The Hang Insulator dialog window opens.
- 1.4 Enter the tower index, 1, and press **Enter** key on keyboard to locate Tower1.
- 1.5 Use the **Length Measurement**  tool in LiPowerline toolbar to measure the length of the insulator. In this project, the length of all insulators is 3 meters. Enter 3 in **Insulator Length (m)**.
- 1.6 Left-click to select the hanging point between insulator and powerline to create the insulator vector object.





- 1.7 Continue this process to finish vectorizing all insulators on 3 powers. There are 6 insulators on each tower in this project.


1.8 Click on **Insulator Editing**  again to stop editing.



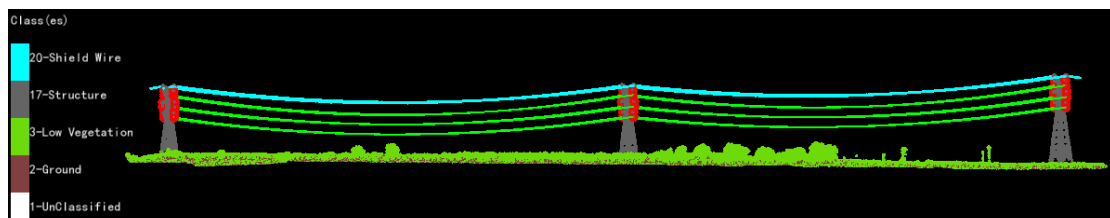
## 2 Vectorize power lines


2.1 Click **Power Line Editing**  to open the power line vectorization toolbar.

2.2 Click **Batch Fitting Power Lines** . In the **Batch Vectorization** dialog window, accept the default number of 1 **Powerline splits number**, and click **Start** to run the tool. All powerlines between insulators are vectorized automatically.

The two shield wires are not vectorized, since they are not involved in the analysis in the following exercise. If shield wire vectorization is necessary in your own project, you can use the **Three Points Fitting Single Power Line**  tool to vectorize the shield wires.





2.3 When finished, vector lines are created and colored in green. Turn on and off the 'Conductor' class display in **Display by Class** tool, and check the fitting quality.

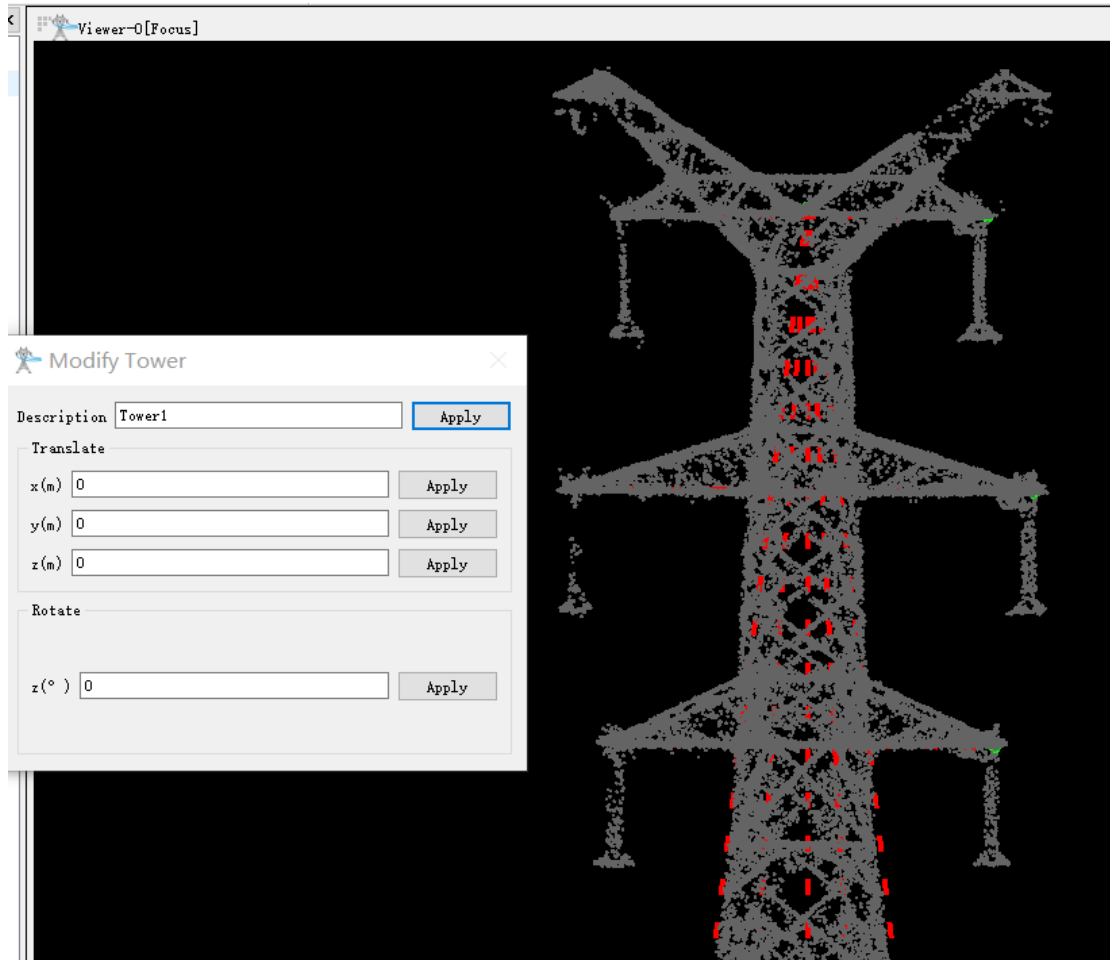


2.4 Click **Save As**  to save the generated power lines as shapefile Powerline.shp.

### 3 Vectorize power towers


To create tower vector objects, tower templates need to be created first. In LiPowerline, user can use the **Create Tower From Five Points** tool to create the template, and use this template to generate tower vector objects with one-click for other towers.


- 3.1 Click **Tower Editing**  to open the tower vectorization toolbar.
- 3.2 Click **Create Tower From Five Points** . This tool generates tower using the bottom 4 points and the top 1 point specified by user.
- 3.3 Click **Display by Class** on toolbar, and uncheck all other classes except for 'Structure' to turn off display of other classes. Click **OK**.
- 3.4 Zoom to Tower1.
- 3.5 Left-click to select the bottom corner 1, 2, 3, and 4 of Tower1 sequentially, and left-click to select the top point of the tower to finish creating one tower model. At any time, you could right-click to end and discard the editing.
- 3.6 Right-click and select **Finish Draw Power Tower** to complete creation of all tower models.
- 3.7 Click **Create Cross Arm**  to add arms to the tower.
- 3.8 Left-click on the tower first, then click to select the end point 1 of the first tower arm, and click to select the end point 2 of the arm.
- 3.9 Repeat this process to finish adding all three arms.
- 3.10 Right-click and select **Finish Draw Power Tower Arm**.
- 3.11 Click **Modify Tower** .
- 3.12 Left-click the tower created above. The **Modify Tower** dialog window opens.
- 3.13 Type in a name for this tower in the **Description**: Tower1. Click **Apply**.




3.14 Right-click to finish modifying.

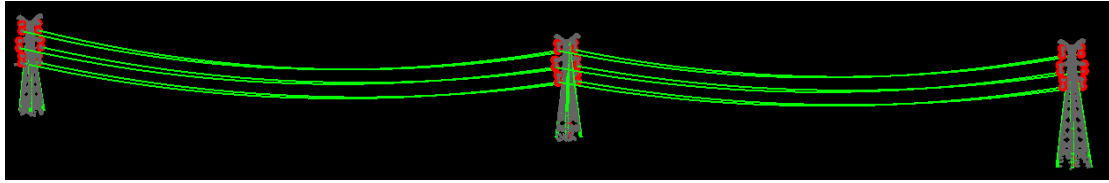
3.15 Click **Save Tower Template** , and save as tower1.tow.

3.16 Click **Load Tower Template** , and select the tower1.tow template file to load to the project.

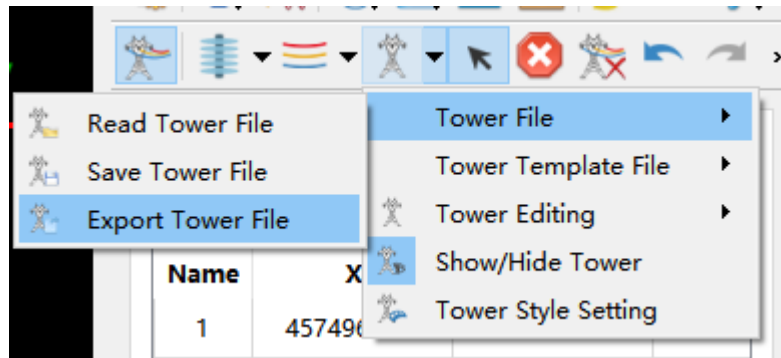
3.17 Zoom to Tower 2, click **Place Tower** , and click on the top of Tower2. In **Place Tower** dialog window, select Tower1 as **Tower Type**. Click **OK** to finish placing the tower.

3.18 Click **Modify Tower** , and type in Tower2 in **Description**. Click **Apply**.

3.19 Zoom to Tower 3. Notice that Tower 3 is taller than Tower 1 and Tower 2. Therefore, repeat step 3.2 to step 3.14 to create Tower 3 model.



3.20 Click **Tower Editing > Tower File > Export Tower File**, to save the tower models as shapefile: Towers.shp.



## Exercise 2: Vegetation encroachment detection

Use the output datasets generated from Exercise 1, or the data provided in SampleData Exercise2345 folder for the following exercise.

### Detecting danger points

Vegetation and other objects encroaching the clearance space in power line corridor should be managed properly for maintaining services and ensuring safety purposes. In this exercise, you will use LiPowerline's **Danger Point Detection** tool to detect vegetation that violates the user defined clearance distances, and to generate a report to present the analysis results to your organization and clients.

- 1 Click **Realtime Working Conditions Analysis**  > **Danger Point Detection**  .

- 1.1 In the **Danger Point Detection** window, add the **1-2(1\_2).LiData** and **2-3(2\_3).LiData** dataset to the **Data File** list.
- 1.2 For **Data Type**, select **Based on Point Cloud**.

In this sample dataset, the data acquisition quality is good and power line points are dense. Therefore, **Based on Point Cloud Data** Type is used in detecting danger points.

In your own project, if significant amount and/or sections of power line points are missing, for example, the arc of the power line is not completely reproduced, then you should use **Based on Vector Data** method to detect danger points. In that case, select the Powerline.shp file generated from vectorizing power lines as **Vector File**.

1.3 For **Detection Parameter**, accept the default values:

**Min Distance:** All points detected within 0.3 meter of the power lines will be treated as noise and ignored;

**Cluster Threshold:** Two points with distance less than 15 meters are classified as one cluster;

**Max Cluster Range:** If the length of a cluster along the power line direction is larger than 20 meters, break this cluster into several.

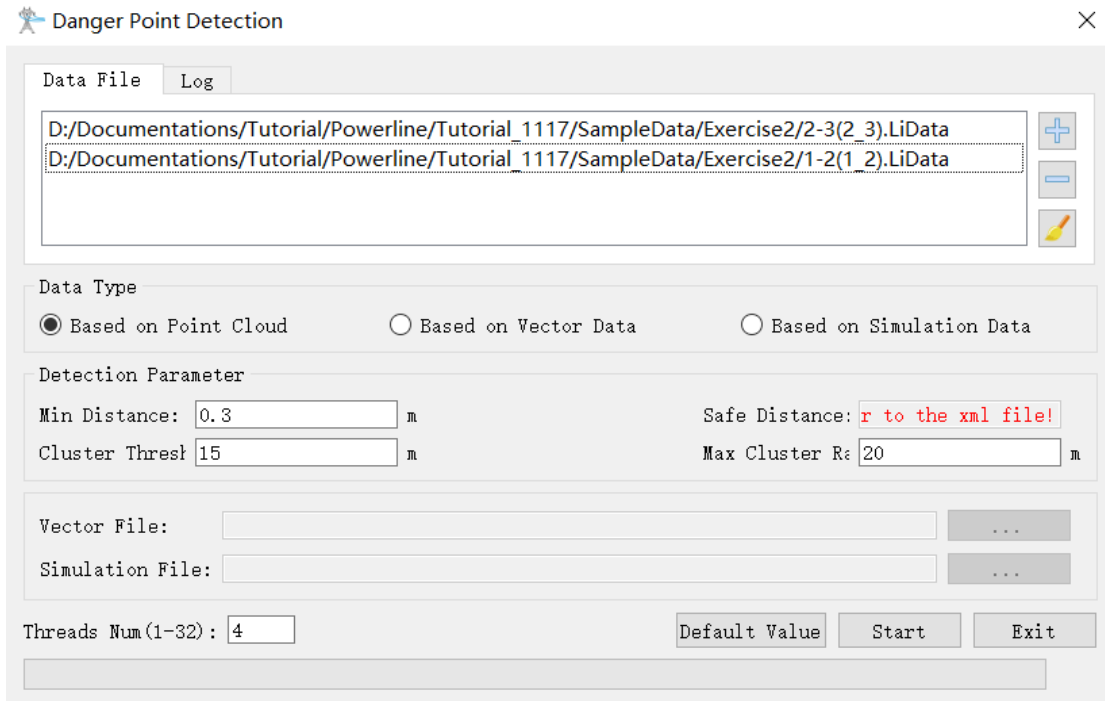
**Safe Distance:** the xml file saved in Classify and Detect Parameters settings will be used for safe distance.

1.4 For **Vector File**, leave it as empty.

1.5 For **Simulation File**, leave it as empty.

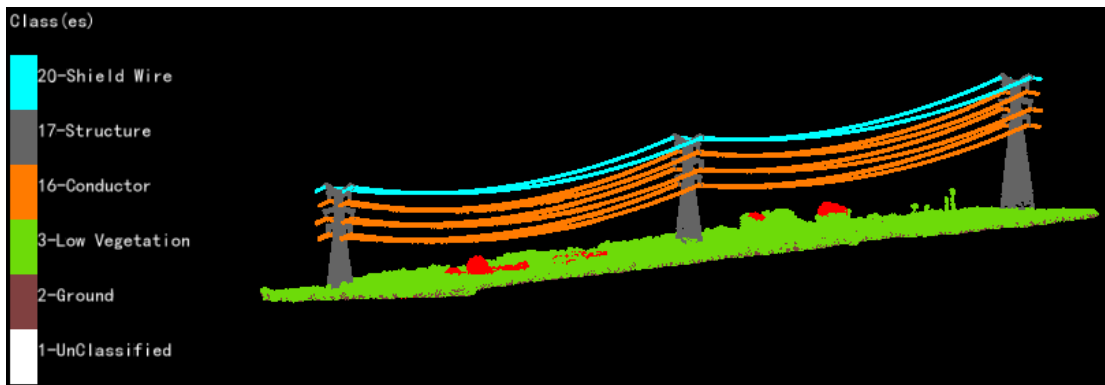
In Exercise 3, we will generate a simulation file under specified weather scenario. You can rerun **Danger Point Detection** analysis using simulation file to detect vegetation encroachment under certain weather conditions.

1.6 Click **Start** to start running **Danger Point Detection** process.

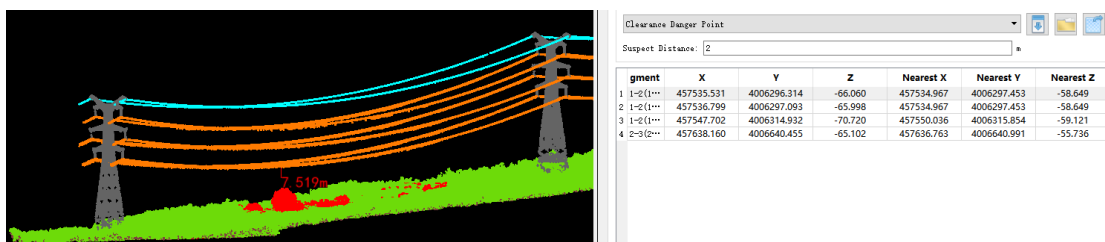


When finished, the points detected as danger will be colored in red, and a table of clusters will be added to the Power Line **Danger Points** window.

In this project, there are four clusters detected as danger points, three in section 1-2, and one in section 2-3.



1.7 Double-click on one row in the table, and the view will center to that cluster and the distance to the power line will be displayed on the view.





## Generating reports

After analysis, the results can be compiled into a HTML report using **Generate Report** tool in LiPowerline, and the clusters of vegetation encroaching power line clearance distance can be exported as KML file.

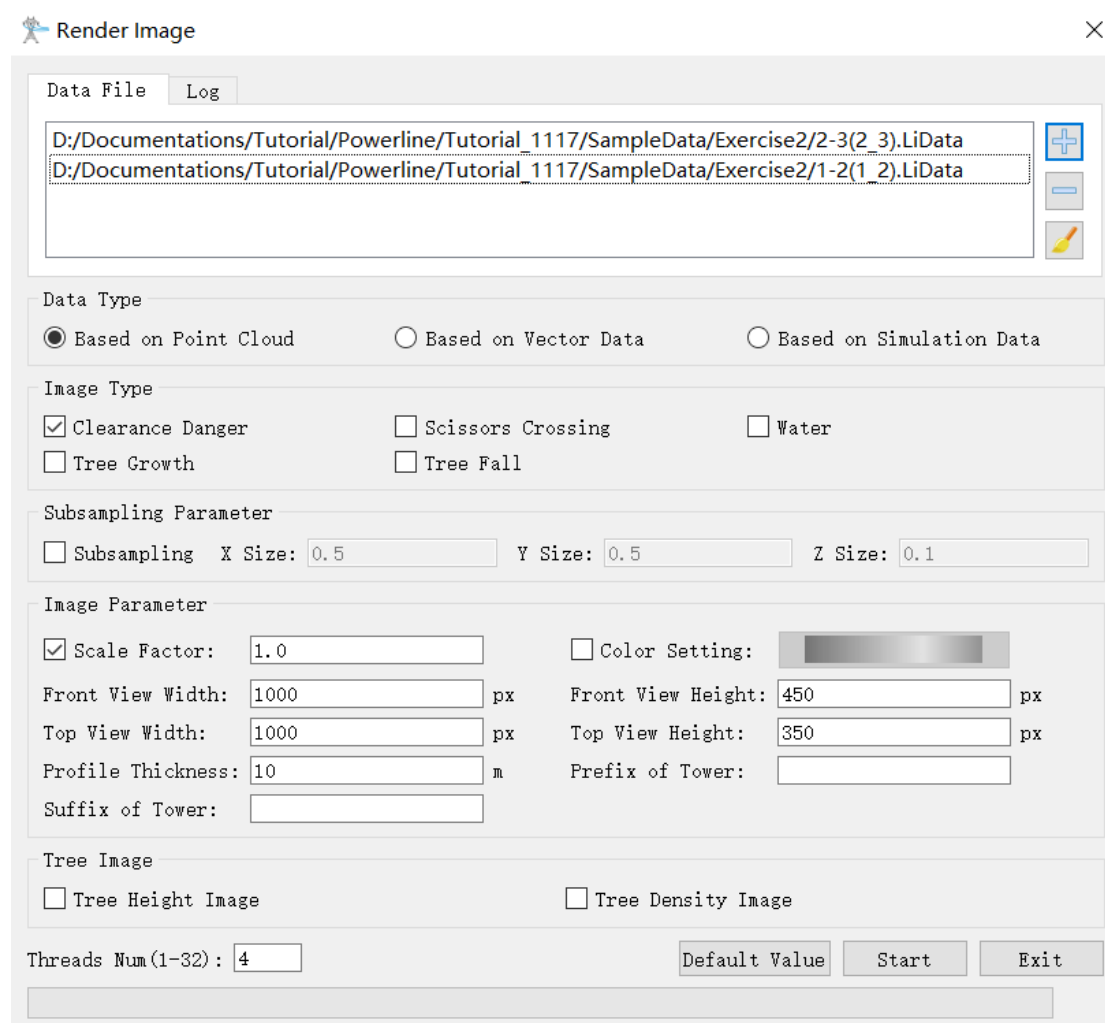
### 1 HTML Report

#### 1.1 Click **Render Image** .

1.1.1 In **Render Image** window, remove all other datasets except for 1-2(1\_2).LiData and 2-3(2\_3).LiData in **Data File** list.

1.1.2 For other parameters, use the default values.

1.1.3 Click **Start** to run.



The screenshot shows the 'Render Image' dialog box with the following settings:

- Data File:** A list containing two files: 'D:/Documentations/Tutorial/Powerline/Tutorial\_1117/SampleData/Exercise2/2-3(2\_3).LiData' and 'D:/Documentations/Tutorial/Powerline/Tutorial\_1117/SampleData/Exercise2/1-2(1\_2).LiData'.
- Data Type:** 'Based on Point Cloud' is selected.
- Image Type:** 'Clearance Danger' is checked. 'Scissors Crossing' and 'Water' are unchecked. 'Tree Growth' and 'Tree Fall' are also unchecked.
- Subsampling Parameter:** 'Subsampling' is unchecked. X Size: 0.5, Y Size: 0.5, Z Size: 0.1.
- Image Parameter:** 'Scale Factor' is checked and set to 1.0. 'Color Setting' is set to a grayscale gradient. Front View Width: 1000 px, Front View Height: 450 px, Top View Width: 1000 px, Top View Height: 350 px, Profile Thickness: 10 m, Prefix of Tower: (empty).
- Tree Image:** 'Tree Height Image' and 'Tree Density Image' are both unchecked.
- Threads Num(1-32):** 4
- Buttons:** 'Default Value', 'Start', and 'Exit'.

1.1.4 Click **OK** when finished.

1.2 Click **Generate Report**  to generate a report in HTML.

1.2.1 Fill in Company names and other parameters under **Generate Report** session if necessary.

1.2.2 Set **Report Path** to working directory.

1.2.3 Click **Start**.

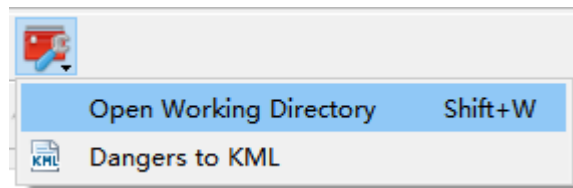
1.2.4 When finished, click **OK** in the **Success** window.

1.2.5 The report automatically opens in your default browser.

If your default browser is Internet Explorer and if ActiveX control warning pops up, enable ActiveX control to open the report.

2 Danger points in KML file

2.1 Click **Tool Box > Dangers to KML**.



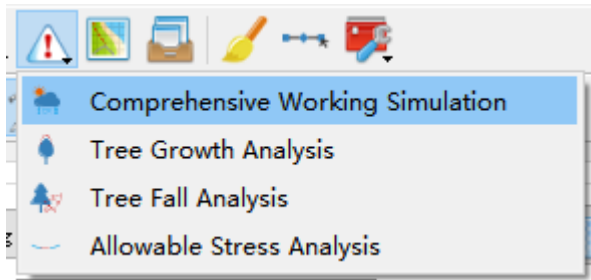
2.2 Select output folder and click **Start** to run the tool. The danger points and area are exported as KML file.

### Exercise 3: Weather condition simulation

Early warning is important to predict and prevent hazards and interruption of services. When weather condition changes, the wire condition, such as swag and sag, changes too. The **Comprehensive Working Simulation** tool in LiPowerline simulates corresponding condition of power line under certain weather scenarios. The result is a simulation file .LiSim which can be used in other analysis such as Danger Point Detection to early warning. In this exercise, with the sample point cloud dataset scanned in summer, we will simulate the condition of the wires in a winter weather scenario.

Please use the output datasets generated in the above exercises, or the data provided in SampleData Exercise2345 folder for the following exercise.

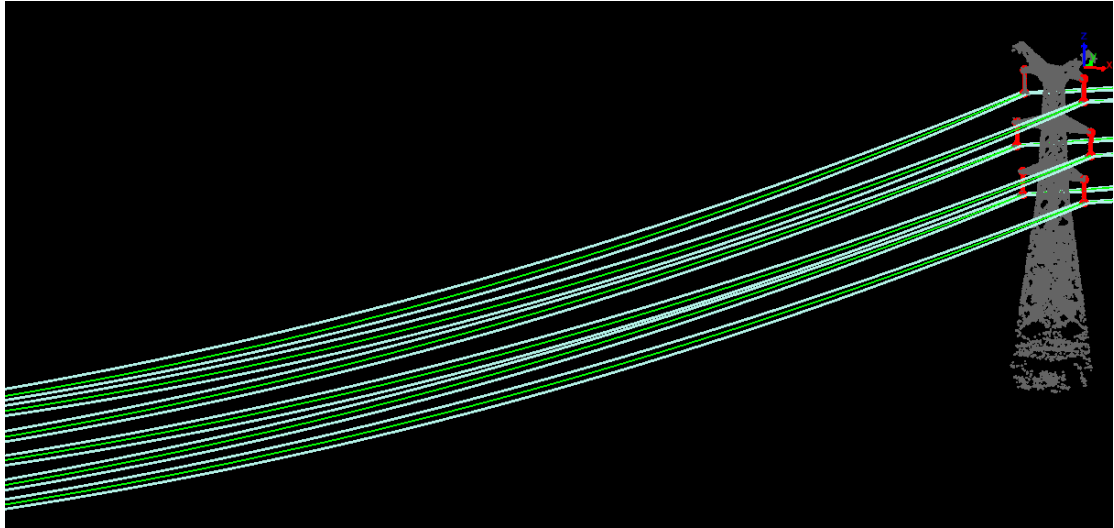
1 Click **Early Warning Analysis > Comprehensive Working Simulation**.



- 1.1 In **Work Conditions Simulation** dialog window, select the Powerline.shp file generated in Exercise 1 as input file, or use the file in the downloaded folder 'Exercise2345'.
- 1.2 For **Insulator File**, select the AttachmentFile.txt generated in Exercise 1, or use the file in the downloaded folder 'Exercise 3'.
- 1.3 Set **Output File** as Simulation.LiSim in working directory.
- 1.4 For **Scanning Conditions**:
  - 1.4.1 Wire Temperature: 15°C
  - 1.4.2 Ice Thickness: 0mm
  - 1.4.3 Wind Speed: 0m/s
- 1.5 For **Simulation Conditions**:
  - 1.5.1 Wire Temperature: -10°C
  - 1.5.2 Ice Thickness: 10mm
  - 1.5.3 Wind Speed: 10m/s
- 1.6 Click **Start** to run the tool.

When finished, a Simulation.LiSim file and a Powerline-simulation.shp file is generated. The simulation file can be used in **Danger Point Detection**, **Tree Fall Analysis**, **Tree Growth Analysis**, and other analysis.

Import the Powerline-simulation.shp file to the map. Notice that the vector objects indicates the wire conditions under user-defined weather scenario.



## Exercise 4: Tree fall hazard prediction

**Tree Fall Analysis** in LiPowerline can be used to detect potential danger points if a tree falls and encroaches the clearance distance of the power lines.

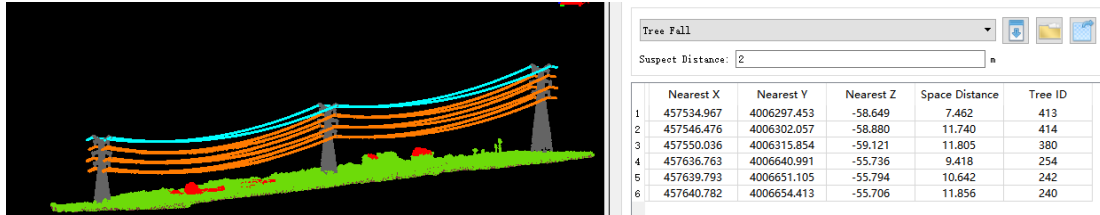
Use the output datasets generated from Exercise 1, or the data provided in SampleData Exercise2345 folder for the following exercise.

- 1 In Power Line panel, click **Early Warning Analysis**  > **Tree Fall**


**Analysis**  .

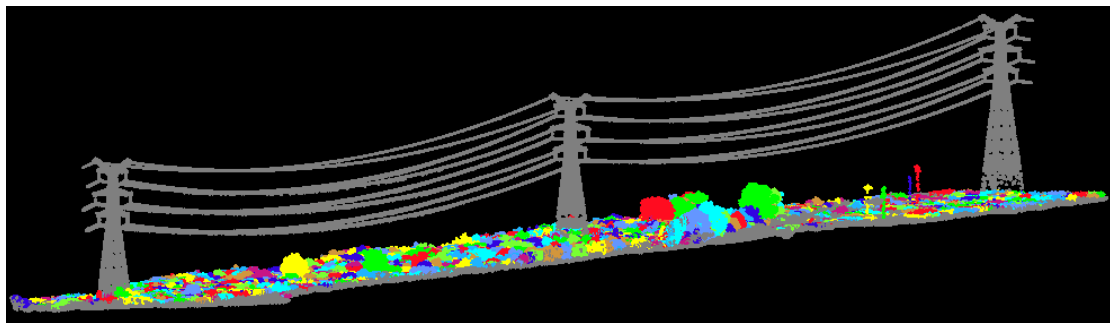
- 1.1 Remove all datasets from **Data File** except for **1-2(1\_2).LiData** and **2-3(2\_3).LiData**.
- 1.2 Choose **Based on Point Cloud** for **Data Type**.
- 1.3 Accept default values for other parameters and click **Start** to run the analysis.

When finished, a table of trees analyzed will be added to the Power Line **Tree Fall** window with locations, nearest power line, space distance, etc.



1.4 Double-click a danger tree to locate it in the view.

1.5 Click **Display by Tree ID**  in **Display** toolbar. Tree Fall Analysis in LiPowerline is based on tree segmentation. Therefore, after this process, individual trees are segmented.



## Exercise 5: Vegetation growth prediction

Tree growth can be simulated on single tree level according to given growing rate and years. Trees that will violate the clearance distance of power lines will be detected in **Tree Growth Analysis**.

Use the output datasets generated from Exercise 1, or the data provided in SampleData Exercise2345 folder for the following exercise.

1 In Power Line panel, click **Early Warning Analysis**  > **Tree Growth**

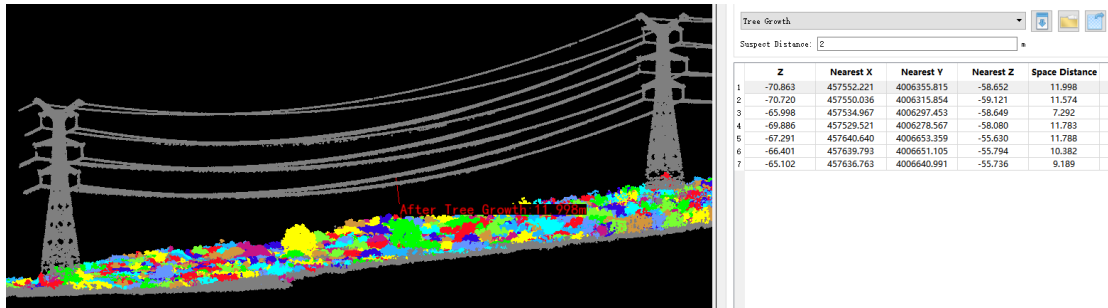
**Analysis**  .

2 Remove all datasets from **Data File** except for **1-2(1\_2).LiData** and **2-3(2\_3).LiData**.

3 Choose **Based on Point Cloud** for **Data Type**.

4 Accept default values for other parameters and click **Start** to run the analysis.

- 5 When finished, a table of trees analyzed will be added to the **Power Line Tree Growth** window with locations, nearest power line, space distance, etc..
- 6 Double-click a danger tree to locate it in the view.



## More resources

Have feedbacks or questions? Please post on our active [Forum](#) to share your ideas and interact with the GVI community, or email us at [info@greenvalleyintl.com](mailto:info@greenvalleyintl.com).

For technical articles, user stories, and other product information, please visit our official website <https://greenvalleyintl.com/>.