Contour line simplification using minimum energy splines

1. List of directories

The supplementary data are formed by four directories:

`\src`
Source code in C++, containing 32 classes, bundled as the Visual Studio 2019+ project.

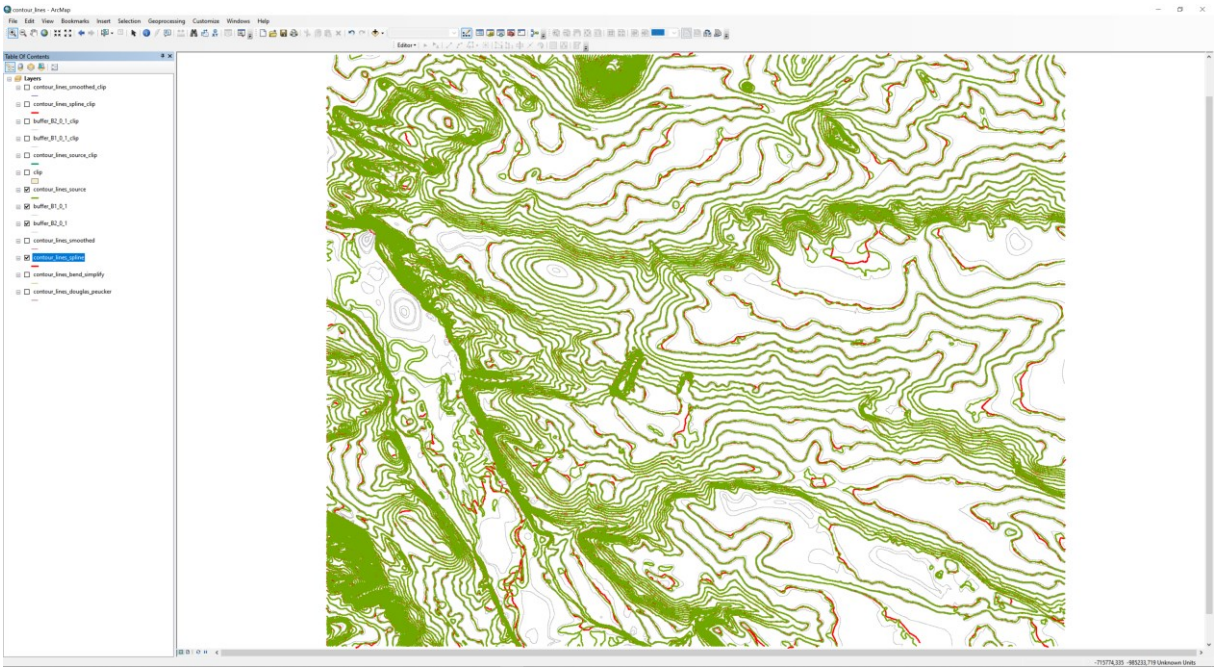
`\bin`
An executable file (exe) together with the batch file (bat).

`\gis`
Source contour lines (input data), simplified by the minimum energy splines, Douglas-Peucker and Bend simplify methods (output data) bundled as ArcGIS 10.7 project.

`\sample`
Small area clipped from the original territory containing contour lines inside the interval 270-288 m. All contour lines together with the vertical buffers are exported into *.csv files.

Overview of the files

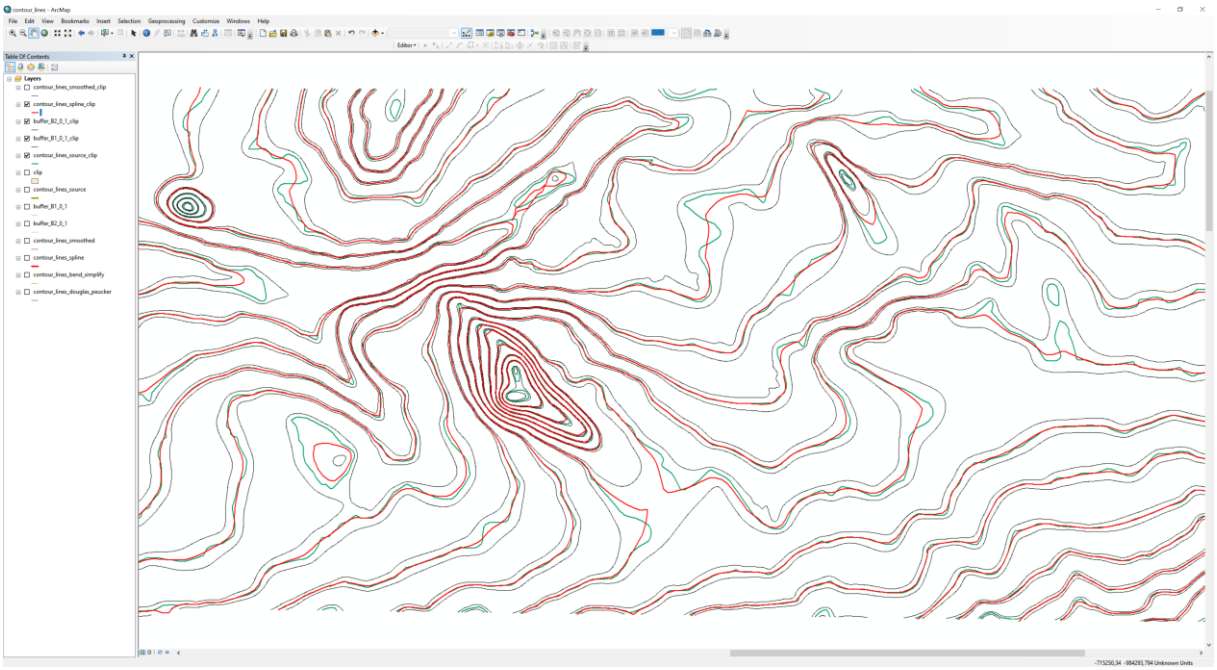
The ArcGIS 10.7. project contains the following shapefiles:



contour_lines_source: Raw contour lines acquired from the point cloud with artificial oscillations.
buffer_b1_0_1: Vertical buffers h -dh constructed to the raw contour lines; dh = 0.1m.
buffer_b2_0_1: Vertical buffers h + dh constructed to the raw contour lines; dh = 0.1m.
contour_lines_smoothed: Smoothed contour lines using the method of simplification potential.
contour_lines_spline: Resulting contour lines created by minimum energy splines.

contour_bend_simplify: Resulting contour lines created by the Bend simplify method (ArcMap 10.7) with barrier polygons formed by the vertical buffer.
contour_douglas_peucker: Resulting contour lines created by the Douglas-Peucker method (ArcMap 10.7) with barrier polygons formed by the vertical buffer.

Small area clipped from the original territory uses the _clip suffix.



Running the sample script

The source files in C++, bundled as the Visual Studio 2019+ project, are stored in the `\src` folder, the output binary file

```
SimplifyCountourLinesEMS.exe
```

is located in the `\bin` folder. Our development version of the simplification software covers C++ 17 language norm and uses -02 compilation flag. To run a program in the command prompt, use the following syntax

```
SimplifyContourLinesEMS.exe +par1=val1 +par2=val2 +par3=val3
```

List of available options:

`+alpha`
Setting value of α parameter of the spline, default value α=0.1.

`+beta`
Setting value of β parameter of the spline (tension), default value β=0.0001.

`+gamma`
Setting value of γ parameter of the spline (stiffness), default value γ=0.0001.

`+lambda`
Setting value of λ parameter (A + λI), default value λ=15.

`+iter`
Setting number of iterations, default value 600.

`+min`
A minimum amount of contour line vertices, default value 20.

`+buff1`
File mask for contour line buffers z – dz. All files matching the mask ale loaded, * is the wildcard.

`+buff2`
File mask for contour line buffers z + dz. All files matching the mask ale loaded, * is the wildcard.

`+cont`
File mask for contour lines. All files matching the mask ale loaded, * is the wildcard.

`+file`
Output DXF file name.

`+path`
Specify a path to the folder with input files, folders are separated by a double backslash, wildcard matching by * is supported.

Additional libraries:
Visual C++ Redistributable installs Microsoft C and C++ (MSVC) runtime libraries. These libraries are required by many applications built by using Microsoft C and C++ tools:

https://docs.microsoft.com/en-US/cpp/windows/latest-supported-vc-redist?view=msvc-170

Please, download and install the correct version of MSVC runtime libraries before running the script.

Example

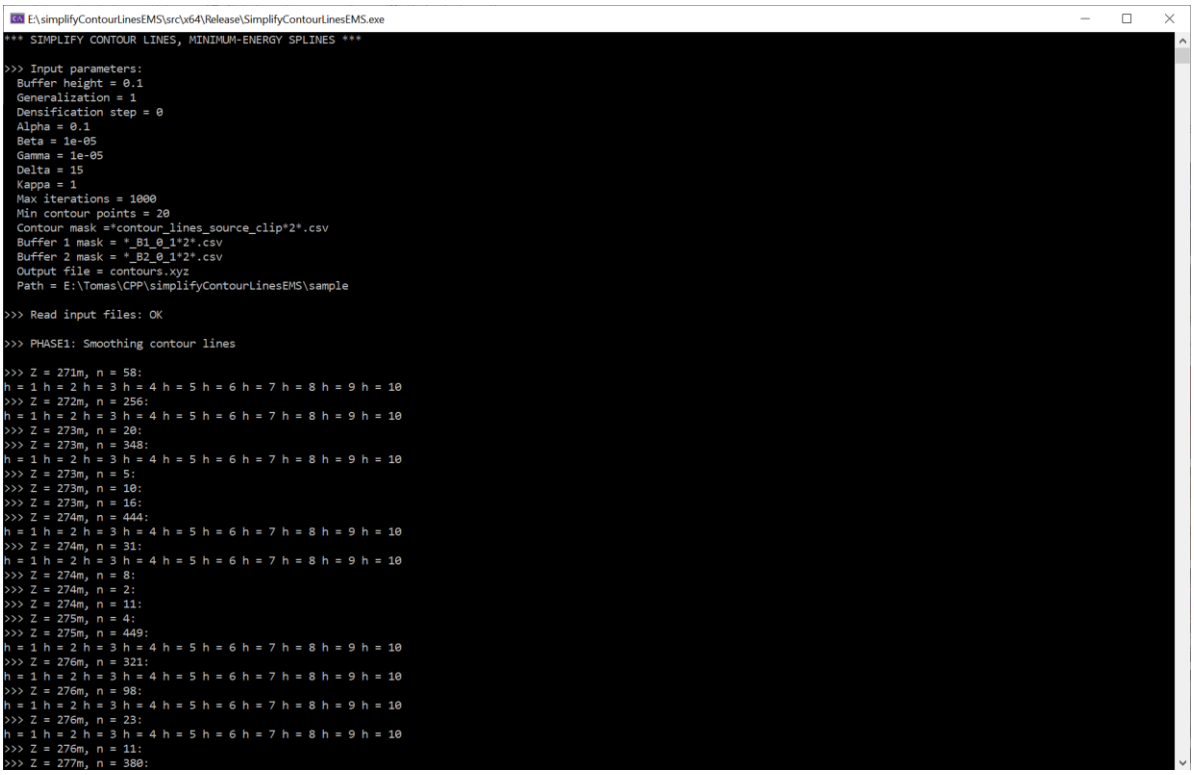
Process contour lines within the height interval 200-300 meters, containing more than 20 points, the maximum number of iterations set to 700. The contour lines vertices and associated vertical buffers vertices given by coordinates [x, y, z] are stored in `*.csv` files. Every contour line or buffer use its own `*.csv` file:

```
-716872.9069652680 -984220.9672773853 272.9
-716872.8133052307 -984221.1866944636 272.9
-716872.6810445486 -984221.5000000000 272.9
-716872.6289253812 -984221.6289254113 272.9
-716872.3300277184 -984222.3300274462 272.9
```

Their names

```
contour_lines_source_clip.shp_CL_272.0_58.csv
buffer_B1_0_1_clip.shp_CL_271.9_2.csv
buffer_B2_0_1_clip.shp_CL_272.1_1.csv
```

refer to the height of the contour line and its vertical buffer.



For the corresponding script, see the `simplify.bat` file located in the `\bin` folder:

```
SimplifyContourLinesEMS.exe +alpha=0.1 +beta=0.00001 +gamma=0.00001
+lambda=15 +iter=700 +min=20 +buff1=*_B1_0_1*2*.csv
+buff2=*_B2_0_1*2*.csv +cont=*contour_lines_source_clip*2*.csv
+file=contours_simplified +path=..\\sample\\
```

The simplified contour lines provided by the energy minimizing splines are stored in DXF file. Despite the simplification process being computationally expensive, the results are obtained within 5 minutes.

All results are also available in the DGN format, see `\sample` folder, and can be visualized in CAD/GIS SW (MicroStation or AutoCAD).