

NetworkGT Toolbox

Version 0.1

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1.0 Background

1.1 Citation and Acknowledgments

The NetworkGT (Network Geometry and Typology) Toolbox is a set of tools designed for the geometric and topological analysis of fracture networks in QGIS 3.4 >. This is a pre-release beta version that is currently under construction. The toolbox provides a range of tools that allow the user to utilize a number of traditional sampling methods in order to automatically conduct a robust characterization of the networks geometric and topological properties as well as assessing its spatial variability. The toolbox has been designed and made publically available by the authors of this workflow, all of whom are academic geoscientists. The different types of analyses are described and discussed in detail within the corresponding article by Nyberg et al., 2018 published in *Geosphere*. If you use this toolbox for your own analyses or research we require that any corresponding results, reports, publications or presentations to CITE AND ACKNOWLEDGE both:

- a) The NetworkGT Toolbox
- b) Nyberg, B., Nixon, C.W., Sanderson, D.J., 2018, NetworkGT: A GIS tool for geometric and topological analyses of two-dimensional fracture networks. *Geosphere*, v. 14, no. 4, p.1-17, doi:10.1130/GES01595.1.

1.2 License

The scripts used in this program are written in the Python programming language under a GNU General Public License V3 which states:

“This program is free software: you can redistribute it and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation, either version 3 of the License, or (at your option) any later version.

This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License for more details.

You should have received a copy of the GNU General Public License along with this program. If not, see <<http://www.gnu.org/licenses/>>.”

2.0 Installation

2.1 NetworkGT Download

Download the latest release of the NetworkGT toolbox

<https://github.com/BjornNyberg/NetworkGT/releases>

2.2 QGIS Installation

QGIS is an open source GIS software that is available Linux, OSX and Windows from

<https://www.qgis.org/en/site/forusers/download.html>. Download the OSGeo4W

Network Installer (64bit) and follow the instructions.

2.3 Python Installation

2.3.1 Python module installation

The toolset utilizes a set of scientific third-party modules that are typically not available in a standard QGIS installation. To install these modules **requires admin rights** and the following procedure:

1. Navigate to the python 3.X folder that contains a python.exe file of your QGIS installation. On windows this is located in 'C:\OSGeo4W64\apps\Python37'
2. Double click the **python.exe**
3. Type **import subprocess** and hit enter
4. Type **import sys** and hit enter
5. Type **subprocess.call([sys.executable, '-m', 'pip', 'install', 'pandas'])** and hit enter

Python modules have now been installed!

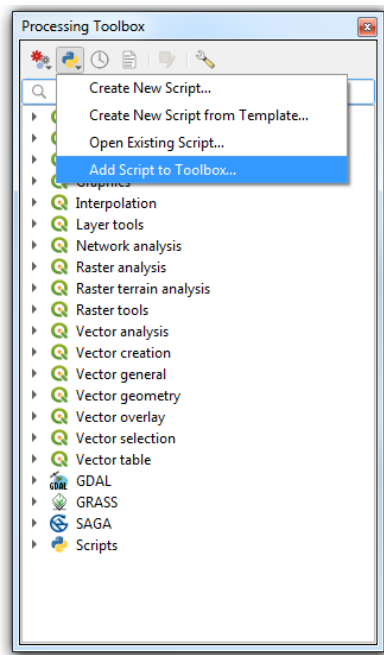
2.4 NetworkGT Toolbox Installation

1. Unzip the NetworkGT-version.zip file into a working directory
2. Open QGIS
3. Find the Toolbox by navigating to the tabs **Processing → Toolbox**
4. Click on the **Scripts** icon → **Add Script to Toolbox...**
5. Navigate to the NetworkGT/QGIS/Scripts folder, select all and open the files

The toolbox is now ready for use under the Scripts -> NetworkGT tab!

Tip - Install the Data Plotly plugin for interactive visualization of your fracture network attributes!

1. Navigate to **Plugins -> Manage and Install Plugins...**
2. Search for **Data Plotly**
3. Press **Install Plugin**



3.0 Workflow (Under Construction)

3.1 Digitizing Fracture Network

3.1.1 Interpretation of Fracture Network

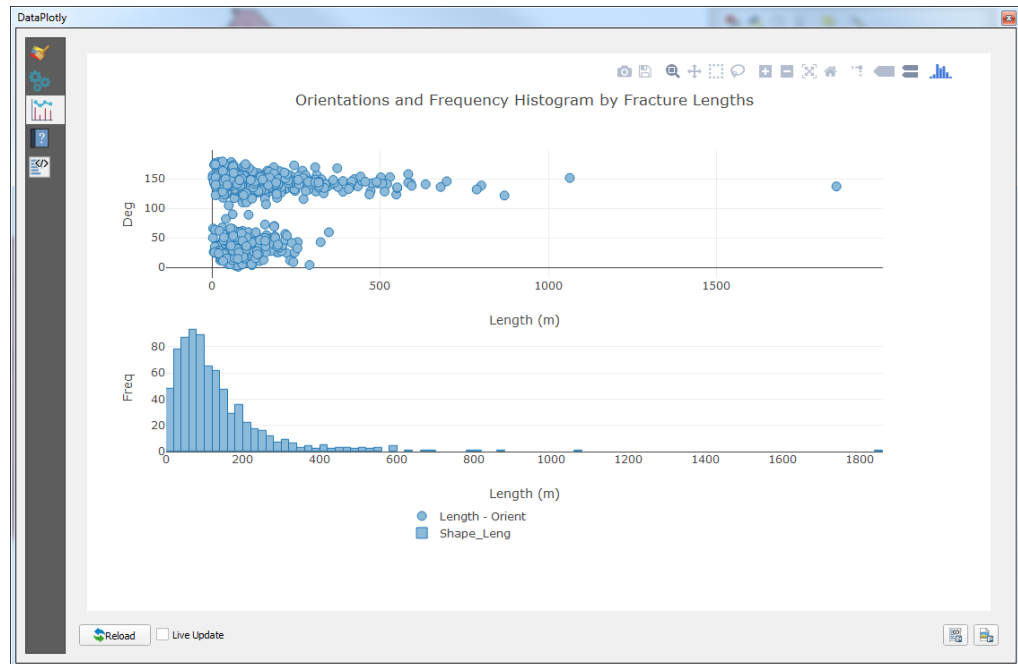
- The fracture network needs to be digitized correctly as polylines at the interpretation stage.
- It is important to always use the 'snap' function when creating fracture polylines.
- This should be used to snap to another fracture polyline if the two fractures are intersecting or to the interpretation boundary polygon if the fracture leaves the interpreted region.

3.2 Geometrical Analysis

3.2.1 Fracture Sets

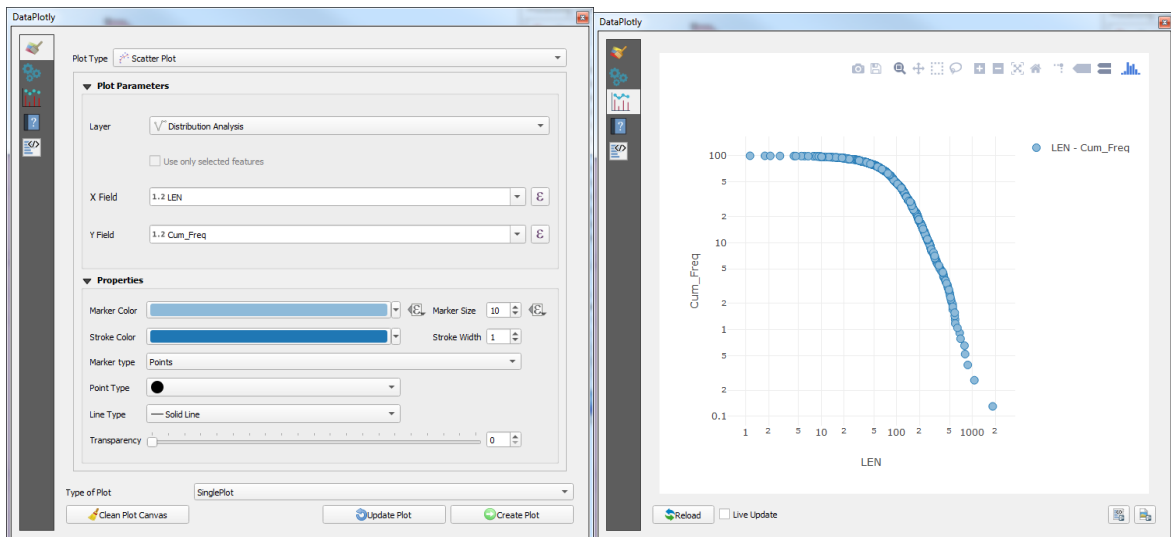
- The 'Define Sets' tool will define sets by orientation.
- This uses the fracture network polyline feature class as the input.
- Note that set orientations ranges must be between 0-180 degrees and defined within brackets, with each set separated by a comma – (0,90), (90,180)
- Set definitions by bin size will define sets into a series of equal bin size increments – e.g. bin size 10 = (0,10),(10,20),(20,30)...
- The orientations and set numbers will be added automatically to the fracture network attribute table, allowing the user to then visualize the fracture network based on these.

- Plot the orientations using the interactive DataPlotly package using the Plot Type 'Polar Plot' or 'Scatter Plot' – Select 'Length' for the X Field and 'Orient' for the Y Field.



3.2.2 Fracture-Size Distributions

- Using the fracture network polyline feature class as an input, distributions of fracture lengths, displacements or apertures etc can be analysed using the 'Distribution Analysis' tool.
- These generate a series of fields in the attribute fields including Cumulative Frequency (Cum_Freq), Weighted Length Field (LEN), normalized standard deviation (NSD), log normal standard deviation (LNSD). Display the data using the DataPlotly Plugin selecting the 'Scatter Plot' for the Plot Type, 'Distribution Analysis' as the Layer, 'LEN' for the X Field and 'Cum_Freq' for the Y Field. In the setting tab select 'Logarithmic' for both X Axis Mode and Y Axis Mode to show a power law distribution.
- For histograms of fracture size distributions use the DataPlotly plugin, select Plot Type as 'Histogram' and X Field as Shape_Length



3.3 Topological Analysis

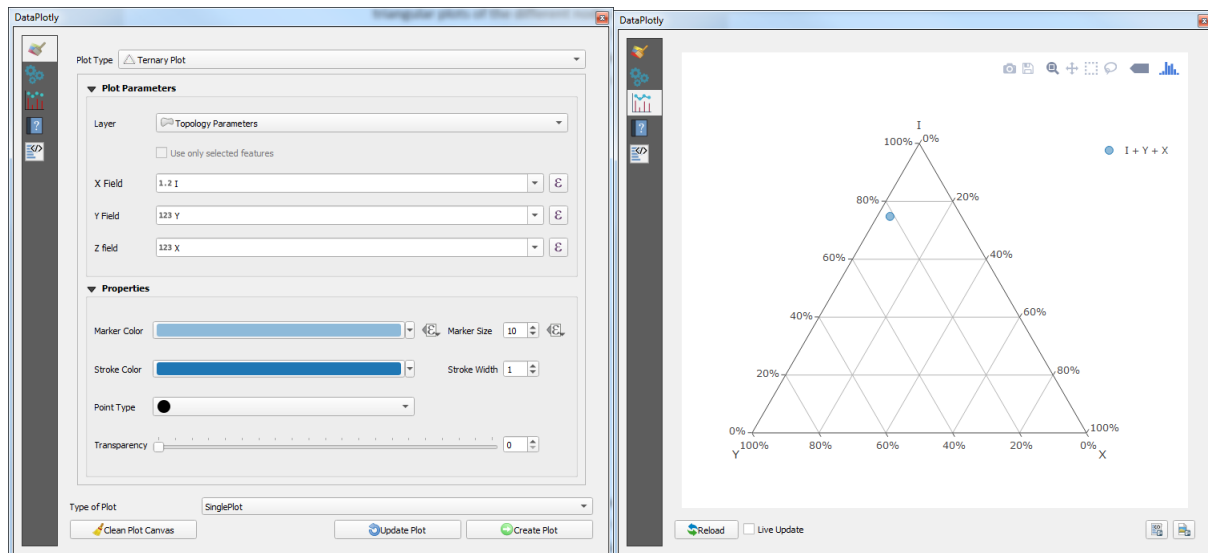
3.3.1 Branches and Nodes

- Branch and node types can be automatically extracted using the 'Branches and Nodes' tool.
- The inputs for this tool are the fracture network polylines, the sample area(s) polygon, and optionally an interpretation boundary polygon can be used.
- The interpretation boundary is important as it defines the limit to which the fracture network can be interpreted. Any fracture that intersects the interpretation boundary polygon creates an edge node.
- The outputs of this tool are two new feature classes: Point Feature Class for Nodes; Polyline Feature Class for Branches.
- The feature classes will have corresponding attribute tables detailing the different node and branch type, each node and branch.
- Nodes identified as errors mean that the network has some inconsistent digitized fracture polylines. This can be useful for identifying if the network needs repairing.

3.3.2 Topological Analysis and Plots

- Once the branch and node feature classes have been extracted in workflow 3.3.1, specific topological parameters can be calculated using the 'Topology Parameters' tool.
- The inputs into this tool are the extracted branch and node feature classes as well as the sample area(s) polygon.
- A duplicate polygon feature class of the sample area(s) is output with a number of calculated parameters added to the attribute table for each sample area, such as node and branch counts, 1D and 2D fracture intensity, connecting node frequency, connections per branch, connections per line...

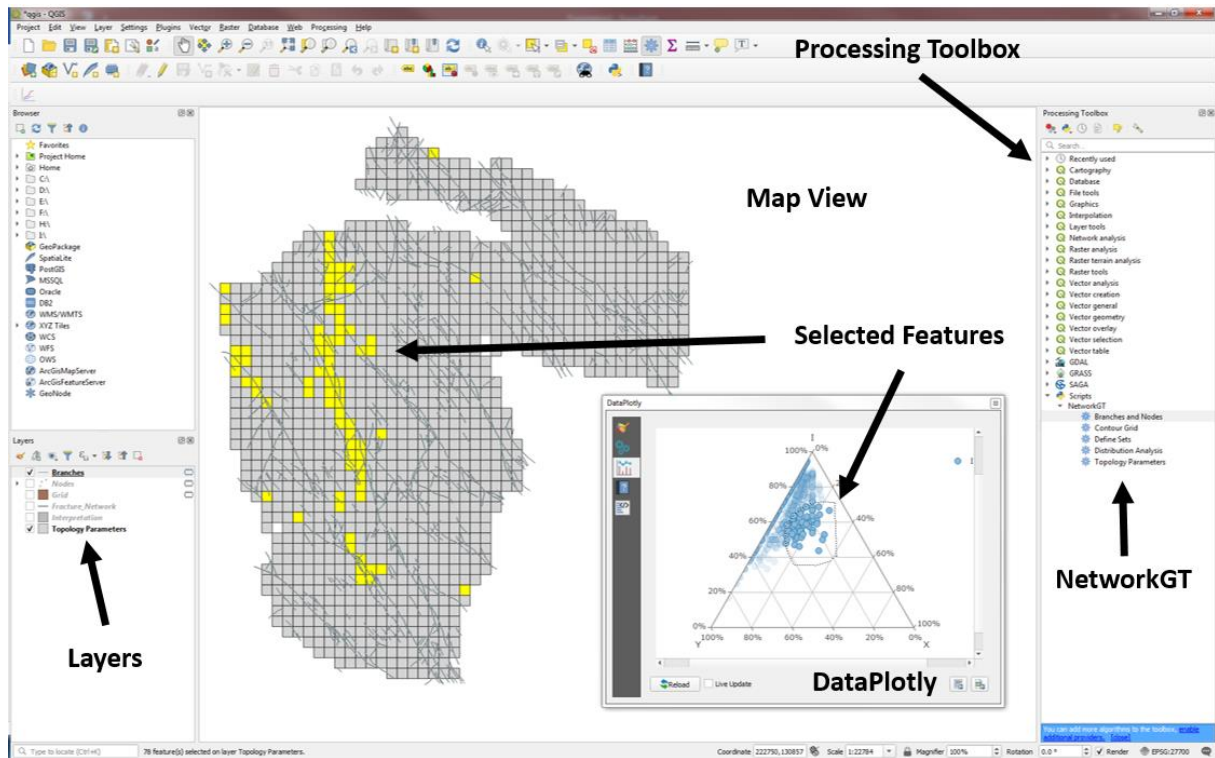
- The 'Topology Parameters' output feature class can be used to create triangular plots of the different node and branch proportions using the DataPlotly Plugin. Select Plot Type as Ternary Plot, populate the X, Y and Z fields with I,Y,X or I –I, I - C and C – C and hit Create Plot.
- Each sample area will be plotted as a dot that may be selected and visualized interactively within the map window.



3.4 Spatial Analyses

3.4.1 Grid Sampling and Contour Plots

- A network of polylines can be sampled by a grid within the interpretation boundary polygon using the 'Contour Grid' tool.
- The tool outputs a polygon feature class of grid cells within the interpretation boundary that systematically sub-samples the network and can be used later to create a contour plot illustrating spatial variations in network properties.
- The tool allows the user to specify the size of the grid cells as well as applying a search radius for sampling branches and nodes associated with each grid cell.
- Branches and nodes should be extracted using the 'Branches and Nodes' tool, following workflow 3.3.1, by using the grid cell polygon feature class as the input for the sample areas.
- This extracts branches and nodes for every grid cell using the search radius to define a circular sample region.
- Topological parameters can be calculated following workflow 3.3.2, by using the extracted branches and nodes for each grid cell as inputs and the grid cell polygon feature class.



4.0 Contact Information & Feedback

Please report any bugs or requests for enhancements on the GitHub NetworkGT repository issues tab <https://github.com/BjornNyberg/NetworkGT/issues>