Developing a Minimal GIS Plugin for Teaching Introductory QGIS

Middlebury

Maja Cannavo and Joseph Holler

Department of Geography, Middlebury College

Abstract

The MiMiGIS ("Middlebury Minimal GIS") plugin for QGIS delivers a set of easy-to-grasp tools that align with fundamental human geography concepts, designed for students in Middlebury's introductory GIS course. The goal of such a "Minimal GIS" concept is, as Marsh, Golledge and Battersby (2007) propose, to focus on development of spatial thinking and comprehension of geographic concepts while lessening the impediment of complicated and sometimes non-intuitive tools. This plugin includes two Processing algorithms, Group By and Direction and Distance. Group By groups features in a layer by values in one or more fields ("group fields") and calculates summary statistics for any number of fields ("summary fields"), with an additional option to dissolve geometries based on the group fields. At this point, no other dissolve tool in QGIS simultaneously allows the choice of multiple group fields and multiple summary fields within a user-friendly interface. Direction and Distance allows the user to calculate the distance and azimuth from an origin point to all features of an input layer. This tool is particularly useful for teaching concepts of urban structure because it allows students to examine spatial relationships between the central business district of a city and the surrounding census tracts or block groups. The plugin also installs a set of Mapbox Maki icons and National Park Service icons with customizable fill color for modifiable SVG symbology. The three aforementioned tools and resources were the ones we judged to be of most immediate need, but we plan to expand the plugin's functionality over time.

Background

Geographic Information Systems (GIS) are notoriously complicated for novice students to learn. Students are simultaneously tasked with learning an array of fundamental concepts for spatial thinking while also learning a very complex and finicky software environment for implementing those concepts. Marsh, Gollege and Battersby (2007) argued for development of a "Minimal GIS" designed to support development of spatial thinking. Essentially, the complexity of desktop GIS software creates cognitive barriers to development of fundamental concepts required for spatial thinking, rather than supporting the process. Marsh et al. envision a GIS that designs algorithms to match fundamental spatial thinking concepts in a framework that begins with the most primitive concepts (e.g. location and location-based nominal, categorical, or quantitative attributes) and gradually progresses to more advanced concepts (e.g. proximity, buffers, scale, spatial interpolation). Intentional sequencing of concepts can reduce the cognitive load associated with problem-based learning in GIS curricula (Howarth and Sinton 2011).

Since the fall of 2018, the introductory GIS course at Middlebury College has been taught using the preeminent open source desktop GIS: QGIS. Like other desktop GIS platforms, there are some internal semantic and logical inconsistencies and deficiencies in its development that both make it more difficult than necessary to learn and make it more cumbersome than necessary to implement some fundamental spatial thinking concepts. At the same time, the open source characteristics of QGIS make it relatively easy to contribute to its future development, including creation and modification of plugins. Teaching an introductory GIS course with QGIS has therefore created both the demand and opportunity to modify GIS software itself to make it more amendable to teaching spatial thinking concepts for studies of human geography (Holler 2019).

The Plugin

During the 2021 Winter Term at Middlebury College, we worked to develop MiMiGIS ("Middlebury Minimal GIS"), a plugin for facilitating introductory GIS instruction. To begin with, the plugin implements three improvements to the QGIS environment:

1. An expanded set of cartography icons drawing on Mapbox's Maki icons and the National Park Service.

2. A "Group By" algorithm for grouping all features by one or more attributes while calculating summary statistics for any number of numerical attributes. This algorithm is similar to the dissolve algorithm offered by other GIS software (e.g. ArcGIS), but developed and explained in a manner that is difficult for students to understand (Holler 2021). The algorithm is necessary for understanding nested spatial hierarchies of aggregate data, or geographic levels of organization similar to the concept of spatial scale. Unfortunately, none of the grouping or dissolving algorithms in QGIS allowed for both multiple grouping attributes and multiple summary attributes. (The Aggregate tool added to the Processing Toolbox with QGIS version 3.16 does include these functionalities, but the interface is non-intuitive and confusing for novice GIS users.)

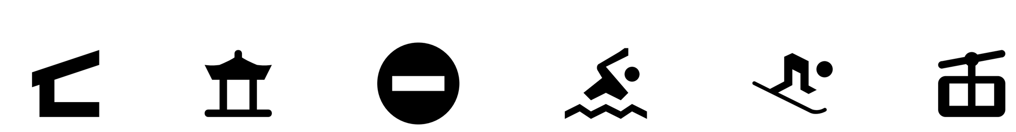
3. A "Direction and Distance" algorithm for calculating the distance and azimuth to all of features of an input layer from a single origin point, allowing the course to teach principles of proximity, direction, and spatial pattern fundamental to understanding the structures of cities in relation to their central business districts.

MiMiGIS is now available as an experimental plugin from the official QGIS Plugins Repository, and is being used in the Spring 2021 Human Geography with GIS course at Middlebury College. We plan to expand the plugin's functionality with new tools and features over time to suit the needs of students in this introductory course. The MiMiGIS GitHub repository with documentation and a download link can be found at https://github.com/GIS4DEV/MiMiGIS.

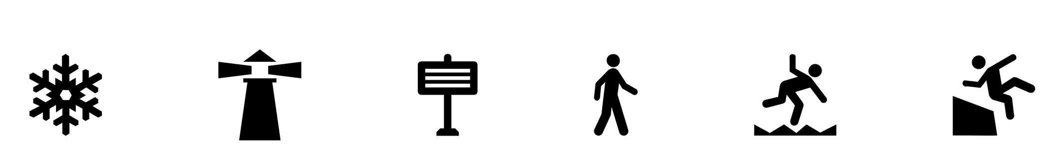
Maki/National Park Service Icons

MiMiGIS.zip contains folders with the Maki and National Park Service (NPS) icons. The plugin automatically adds the paths to these directories to the list of SVG paths in the user's QGIS preferences. The Maki icons were downloaded from Mapbox, and the NPS icons were downloaded from NPS. Both sets of icons were then edited by Joseph Holler to allow for color customization in QGIS.

Maki Icons (Sampling)



NPS Icons



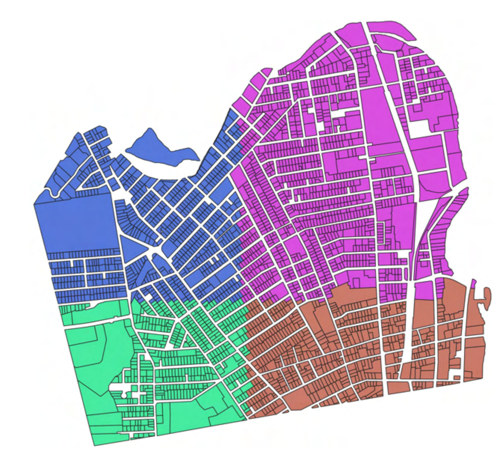
Visit the MiMiGIS GitHub repository at https://github.com/GIS4DEV/MiMiGIS for documentation and a download link.

Group By Algorithm

Groups features with common values in the group field(s). Optionally, dissolves geometries and calculates summary statistics for numeric fields. All outputs have a "featCount" field with the number of features in each group.

Example: Grouping parcels in Central Falls, RI, by zone (NE, NW, SE, or SW) and calculating feature count and average for number of bedrooms and total value.

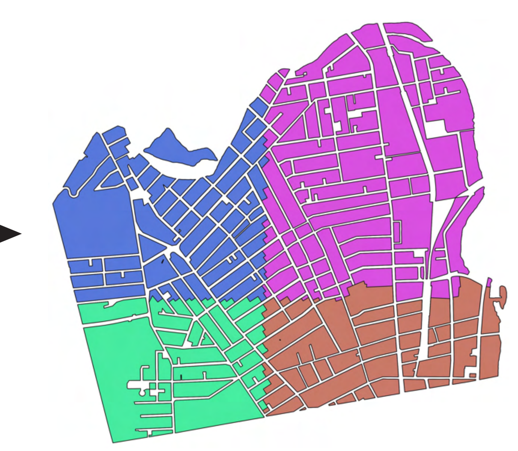
Example Input



StreetNum	StreetName	Bedrooms	TotalValue	Zone
276	HUNT ST	6	218800	NE
30	COWDEN ST	10	221300	NE
75	RAND ST	3	222400	SE
46	SCHOOL ST	2	222500	NW
32	SYLVIAN ST	12	224500	NE
615	PINE ST	5	225300	SW
77	GARFIELD ST	6	226600	SE
33	RICHARDSON ST	4	226700	SW

.
.
.

Example Output



featCount	Zone	cntBedroom	cntTotalVa	avgBedroom	avgTotalVa
1131	NE	1131	1131	5.881520778	271197.878
758	NW	758	758	4.790237467	165931.9261
571	SE	571	571	5.338003503	208170.4028
449	SW	449	449	5.267260579	163066.147

Algorithm Parameters:

Parameter	Description	Data Type	Python Identifier
Input layer	Input layer with features to be dissolved.	Vector	'INPUT'
Group Fields (optional)	In which field(s) do you want to search for values with which to form the new groups? A new group will be formed for each combination of values in the group field(s). If you do not select any group fields, the output will be a single feature.	Field(s)	'GROUPFIELDS'
Summary Fields (optional)	Which numerical field(s) do you want to calculate summary statistics for?	Numerical field(s)	'SUMMARYFIELDS'
Dissolve Geometry	Do you want to dissolve the geometries (geographic data) associated with the features? Disjoint geometries are still dissolved into multi-part features. If this option is unchecked, the output will be a table with no geographic data.	Boolean	'DISSOLVEGEOMETRY'
Average	Calculate the average or mean of your summary field(s)?	Boolean	'AVERAGE'
Count Values	Count non-null values in your summary field(s)?	Boolean	'COUNTVALUES'
Sum	Calculate the sum of your summary field(s)?	Boolean	'SUM'
Maximum	Calculate the maximum of your summary field(s)?	Boolean	'MAXIMUM'
Minimum	Calculate the minimum of your summary field(s)?	Boolean	'MINIMUM'
Grouped Output	Grouped output. If you are not dissolving geometries, then save the output as a .csv, .xlsx, or database table.	Feature Sink	'OUTPUT'

Author Contact Information

Maja Cannavo, Middlebury College '21
mcannavo@middlebury.edu
https://majacannavo.github.io/

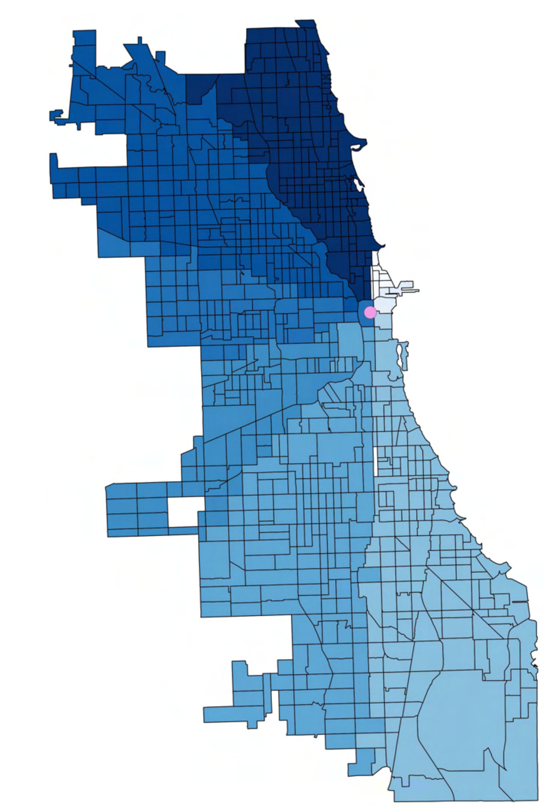
Joseph Holler, Assistant Professor of Geography, Middlebury College
josephh@middlebury.edu
https://www.josephholler.com/

Direction and Distance Algorithm

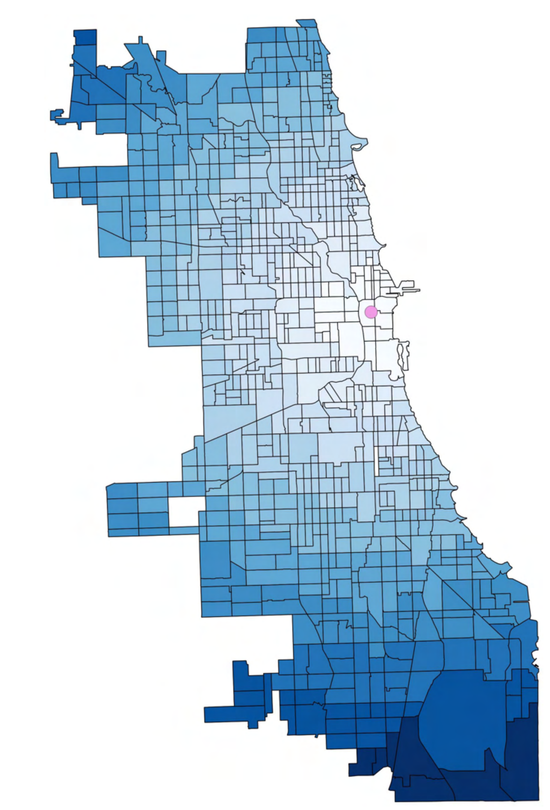
Calculates the distance (in meters) and direction (in degrees) from an origin to a set of input features. Distance calculation is ellipsoidal, using the WGS 1984 geographic coordinate system (EPSG:4326). Direction calculation uses the World Mercator projected coordinate system (EPSG:3395).

Example: Calculating direction and distance from Chicago's central business district to each of the city's census tracts.

Example Direction Result



Example Distance Result



Example Input Attribute Table

TRACTCE10
10100
10201
10202
10300
10400
10501
10502
10503

.
.
.

Example Output Attribute Table

TRACTCE10	originDist	originDir
10100	15881.6547	348.028596
10201	15517.5473	344.492782
10202	15380.4962	346.529912
10300	15247.3033	348.576077
10400	13929.7987	350.044613
10501	14494.3263	348.835651
10502	13950.9535	348.613611
10503	13490.8952	348.291601

.
.
.

Algorithm Parameters:

Parameter	Description	Data Type	Python Identifier
Input Layer	Layer of features for which to calculate direction and distance from the origin.	Vector	'INPUT'
Origin	Origin feature from which to calculate direction and distance.	Vector	'ORIGIN'
Prefix	The algorithm creates two new fields, one with suffix 'Dist' for Distance and one with suffix 'Dir' for Direction. Enter a prefix to use for the field names, such that you will not create duplicate fields in your output.	String	'PREFIX'
Dir/Dist Output	New layer with direction and distance fields.	Feature Sink	'OUTPUT'

References

Holler, J. (2019). Human Geography With Open GIS as a Transformative Introductory Higher Education Course. ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLII-4/W14, 99–106. https://doi.org/10.5194/isprs-archives-XLII-4-W14-99-2019

Holler, J. (2020). Teaching critical open GIS. The Canadian Geographer / Le Géographe Canadien, 64(4), 484–494. https://doi.org/10.1111/cag.12521

Howarth, J. T., & Sinton, D. (2011). Sequencing spatial concepts in problem-based GIS instruction. Procedia - Social and Behavioral Sciences, 21, 253–259. https://doi.org/10.1016/j.sbspro.2011.07.042

Marsh, M., Golledge, R., & Battersby, S. E. (2007). Geospatial Concept Understanding and Recognition in G6–College Students: A Preliminary Argument for Minimal GIS. Annals of the Association of American Geographers, 97(4), 696–712. https://doi.org/10.1111/j.1467-8306.2007.00578.x