

INNOVATIVE RESEARCH IN ENGINEERING



Editor
Assoc. Prof. Bayram AKDEMİR, Ph. D.



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QGIS: Open source GIS software and Plugins

Selçuk ALBUT ¹

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SUMMARY

Geographic Information Systems (GIS) have become an essential tool in various fields, enabling the visualization, analysis, and interpretation of spatial data. The accessibility and capabilities of GIS technology have been transformed by open-source GIS software and its vast array of plugins. The QGIS program, well-known for its user-friendly interface, potent capabilities, and a thriving developer community, is one of the major players in this field.

Open-Source GIS Software: Open-Source GIS software refers to applications that are freely available, allowing users to access, modify, and distribute the source code. With the help of this strategy, GIS technology has become more accessible, allowing authorities, institutions, academics, and common people to make use of spatial data without being constrained by the high costs of proprietary software. Due to its cross-platform portability, comprehensive format support, and strong geographic analysis capabilities, QGIS, a top Open-Source GIS program, has grown in popularity.

Plugins for QGIS: What distinguishes QGIS is its ecosystem of plugins, which are modular additions that improve the capability of the program. In order to meet the demands of various users, plugins range from simple utilities to sophisticated analytical capabilities. These plugins can be easily added to the QGIS interface, increasing its functionality without requiring a deep understanding of coding or software development.

Geographic Information System (GIS) Software

A Geographic Information System (GIS) software is designed to retrieve, store, manage, display and analyze all types of geographic and spatial data from other sources. GIS software allows you to create maps and other graphical displays of geographic information for analysis and presentation.

GIS software enables you to produce maps and other graphic representations of geographic data for analysis and presentation. A GIS with these capabilities is an invaluable tool for visualizing spatial data and developing decision support systems for your.

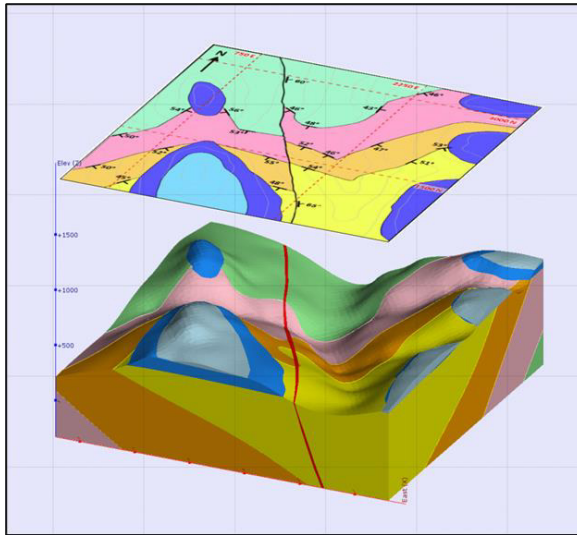


Figure 1. GIS data structure (Seequent, 2023a)

A GIS maintains information about geographic features and their attributes. Typically, features are categorized as points, lines, regions, or raster pictures. Cities, roads, and boundaries can all be represented on a map as points, lines, or areas. Raster pictures can be created from aerial photos or scanned maps.

Spatial indices used by Geographic Information Systems to store data enable the identification of features on any part of a map. For instance, a GIS can swiftly locate and map every place within a certain radius of a point or every street through a specific area.

A GIS software program is a computer program that supports the use of a geographic information system, providing the ability to create, store, manage, query, analyze, and visualize geographic data, i.e. data representing facts for which location is important (Wikipedia.org, 2009). In various information

technology architectures, the GIS software market includes a wide range of commercial and open source applications that offer some or all of these functions.

What is Open Source Code (OSC) software?

Software that is open source (OSC) can have its source code inspected, changed, or improved by anyone. Most computer users never view the "source code," which is the code that allows computer programmers to alter how a software "program" or "application" functions. Programmers can enhance a computer program by adding features or fixing components that don't always function properly if they have access to the source code. (OpenSource.com, 2023).



Figure 2. Open Source Softwares (The Tapmi Blog, 2010)

Let's compare open source Geographic Information System (GIS) software with commercial GIS software. GIS software is software used to collect, store, analyze and map geographic data. Software that is open source allows for anybody to view and edit the original source code. Commercial software, on the other hand, is software that is offered to users through licensing by a company or organization and is usually paid (Eomag, 2017). Some important differences and similarities between open source GIS software and commercial GIS software are:

1-Licensing and Pricing:

- Open source GIS software and commercial GIS software have a number of key distinctions and similarities.
- Commercial software is usually sold by companies under paid licenses and users have to pay to use the software.

2-Community and Support:

- Open source software is usually supported by a large community of developers and users. These communities are active in adding new features, fixing bugs and answering users' questions.
- Commercial software may also have a support team, but it is usually not as large and diverse as the community support of AKK software.

3-Features and Capabilities:

- Commercial software frequently comes with a variety of features and may provide solutions for particular sectors or business requirements.
- Even while it might not have as many capabilities as certain commercial software, open source software may be suited for those with more specialized or specific needs.

4-Security and Updating:

- Security flaws may exist in commercial and open source software. However, since the source code of open source software is publicly available, vulnerabilities can be found and remedied more quickly.
- Commercial software security upgrades may differ based on the company's rules and turnaround time.

5-Customization:

- Open source software can be modified to meet individual user requirements. Users that have access to the source code can modify or add to the software.
- Commercial software frequently provides less flexibility for customization, which may limit how precisely it may be adapted to users' unique requirements.

The user's requirements, financial situation, and technical proficiency will determine whether to utilize open source or proprietary GIS software. Open source software can provide more flexibility and customization whereas commercial software frequently offers more comprehensive functionality and support services. Commercial software might be more suited for consumers who desire a large community of supporters and frequent updates, whereas technically knowledgeable users might prefer open source software.

Development of OCR software might offer viewpoints that go beyond those of a single organization. In the same way that user scripts and custom stylesheets enable websites to be customized to a user's needs, open source code is accessible for use and enables skilled end users to do the same with software. Once customized, the user can publish the change as a fork for users with similar preferences and submit potential improvements directly as pull requests.

Open Source Code (OCR) GIS software

An OCR software application is, by definition, software in which GIS users can freely access and modify the source code. Open source projects are usually worked on by a community of volunteer programmers (Dempsey, 2022).

Numerous benefits of open source GIS include its availability for free, adaptability, and support from a sizable and vibrant user and developer community. Commercial GIS software, such as Esri's ArcGIS Pro, is proprietary and charged for.

Open source GIS usage is expanding quickly, and GIS is playing a bigger role in the spatial business for data production, spatial analysis, visualization, and cartography.

Open source GIS programs are based on different underlying programming languages. In terms of programming languages, there are three main groups of open source GIS (apart from web GIS): "C" languages, Java and .NET.

The first group would be the one that uses the "C++" language for its implementation. This is the more mature of the open source GIS groups, probably for the simple reason that the group has been working on GIS software applications the longest and has a long history of code reuse.

C++ is often used for GIS programming because it is a powerful and versatile programming language that is well suited to the complex and computationally intensive tasks involved in GIS. C++ allows developers to create highly efficient and performant GIS software that can handle large amounts of data and complex geospatial operations.

In addition, C++ has a large and active community of developers who contribute to and support the language, making it a popular choice for GIS programming. The libraries in the C++ group consist of basic infrastructure and some capabilities such as coordinate reprojection that make them very useful and popular.

Popular "C" based open source GIS software applications include GRASS GIS, Geospatial Data Abstraction Library (GDAL) and QGIS (formerly Quantum GIS), a project started by the US Army in 1982 but now open source.

Some of the AKK software include:

- FlowMap
- GDAL
- QGIS
- GMT Mapping Tools
- GRASS GIS
- TNTmips Free
- gvSIG
- MapWindow GIS
- OpenJUMP GIS
- SPRING
- uDig GIS

Some of the web-based AKK software are:

- GeoServer
- MapFish
- MapServer
- OpenLayers
- OpenWebGIS
- MapGuide Open Source



Figure 3. Some Open Source GIS software (GIS Lounge, 2020)

What is QGIS?



QGIS is a professional GIS application built on Free and Open Source Software (FOSS) and proud to be itself. QGIS is a user-friendly Open Source Geographic Information System licensed under the GNU General Public License. QGIS is an official project of the Open Source Geospatial Foundation (OSGeo). It runs on Linux, Unix, Mac OSX, Windows, and Android and supports numerous vector, raster, and database formats and functions (QGIS.org, 2023).

Users can create, edit, and analyze spatial data using the free and open-source GIS program QGIS. It offers a framework for managing many kinds of geographic data, including databases, vector data, and raster data. QGIS enables users to produce high-quality output maps, which can be used for a variety of purposes, including infrastructure development, urban planning, and the management of natural resources. The software has changed over time with regular additions of new features and capabilities since its initial release in 2002.

The fact that QGIS is free to download and use is one of its main advantages. This makes it affordable for a variety of customers around the world, such as schools, NGOs, government organizations, and companies that use GIS services but have a tight budget. A variety of extensions, tools, and add-ons for QGIS are available for free download and installation. This enables users to effectively operate and adjust the software to their unique needs.

QGIS is a flexible piece of software that can be used on a range of devices because it is compatible with different operating systems, including Windows, Mac, and Linux. It is compatible with a wide range of data types, including GeoTiff, PostGIS databases, and picture files. This wide range of compatibility improves the software's usability and versatility and makes it simple for users to import and export their data.

Additionally, QGIS has a simple, user-friendly design that makes it perfect for both novice and experienced users. Users who require assistance with particular activities or features can find extra support in the software's rich documentation, tutorials, and user forums. The software has a wide range of analytical tools and functions and supports drag and drop capability.

Geocoding, geoprocessing, topology modification, and 3D modeling are among QGIS's features. Users can perform geographical analysis on their data,

for instance, by buffering or making a heat map to show regions with high or low point densities.



Figure 4. QGIS 3.28.9 'Firenze' (LTR)

Additionally, QGIS has a large selection of mapping tools that may be used to produce stunning maps and visualizations, such contour maps or thematic maps. Additionally supported by the software are Python, R, and SQL programming languages, enabling users to automate processes and create scripts.

Why QGIS?

Today, as "Geo-Sourced" information becomes more and more widely known, there is no shortage of applications that can perform some or all of the commonly used GIS functions (QGIS.org, 2023a; Gillian and Sparks, 2021). Why use QGIS instead of another Geographic Information Systems (GIS) software package? Here are just a few of the reasons:

- Installing and utilizing QGIS will not cost you anything at all. There are no setup costs, ongoing costs, yearly payments, or anything else. Like freebies, it is also free.
- If you need extra functionality in QGIS, you can do more than hope it will be included in the next release. You can sponsor the development of a feature or add it yourself if you have programming skills.
- QGIS is always changing. Because anyone can add new features and enhance old ones, QGIS will never become stagnant. A new module can be developed as quickly as you require.
- There is a ton of support and documentation accessible. You can consult the rich documentation, other QGIS users, or even developers if you run into any problems.
- QGIS is a multi-platform software. It can be installed on Mac OS, Windows, Linux and Android systems.

There are numerous software programs and apps available in the area of GIS software. The software that has most significantly aided the industry's expansion is QGIS. We can discover the clear justifications for employing QGIS in this blog.

We can summarize the most important features that distinguish QGIS software from other OSC software as follows.

It has a wide "Plugin" architecture. So, what is this Plugin architecture?

QGIS Plugins

Plugin architecture is how QGIS was created. This makes it simple to add numerous additional features and capabilities to the program. In reality, QGIS has several functionalities that are implemented via plugins. QGIS plugins are implemented either as Core Plugins or External Plugins (QGIS.org, 2023b; Gandhi, 2023; GIS OPS, 2019).

QGIS has had a modular architecture that makes it easy to add new features or functions (Packt, 2023). Most functions in QGIS are implemented in so-called plugins, which are divided into the following types:

Core plugins: These are kept up to date by the development team and included with QGIS by default. They should only be triggered by a user in order to be put to use.

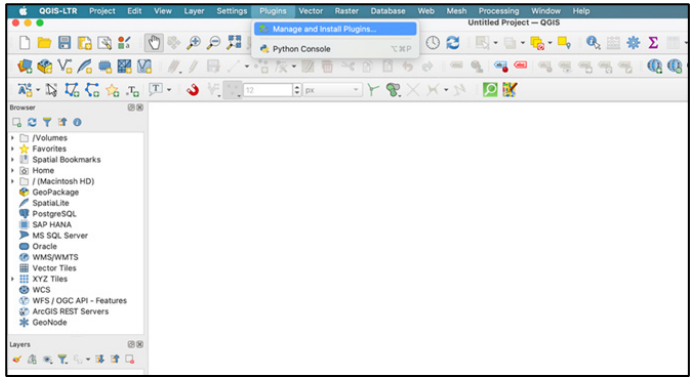


Figure 5. QGIS Plugins menu select.

External plugins: These are kept up by the writers and are kept in an outside repository. They must first be installed by a user before being utilized. As time goes on, some of the most beneficial and well-liked plugins are integrated into the core functionality of QGIS.

The Core Plugins are automatically included in every QGIS release and are updated by the QGIS Development Team. They are written in either Python or

C++, depending on the situation. Python is now used to write the majority of external plugins.

The software QGIS gains important features from plugins. Developers of QGIS and other independent programmers who seek to enhance the software's fundamental features create plugins. After being evaluated by the community and being submitted to the QGIS Plugin Repository, these plugins are subsequently made accessible to all QGIS users.

Managing plugins

Activation, installation, updating, and removal of plugins are all included in their management, which may be done by going to "Plugins / Manage and Install Plugins". The dialog window has a number of tabs (Fig.6). When you click on a specific plugin under one of these tabs, full information is displayed, including links to the plugin's home page, code repository, and tracker as well as details on the plugin's functionality, rating, creator, and whether it is experimental or not:

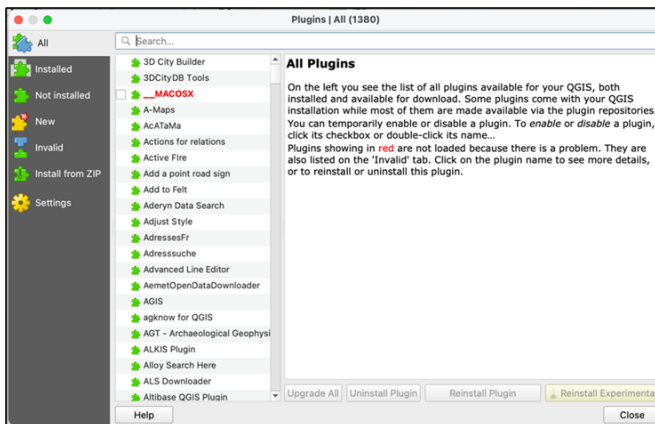


Figure 6. Plugins main window.

- All: The complete list of accessible plugins, both installed and uninstalled, is displayed under this tab.
- Installed: The plugins that are already installed in QGIS are displayed on this tab. Just check or uncheck the toggle next to a plugin's name to activate or deactivate it (Fig.7).
- Not installed: All of the plugins that are accessible but haven't been installed in your QGIS are listed on this tab.

The following tabs are not always visible and are only displayed in the event that certain plugin requirements are met:

- New: This tab shows the not-installed plugins seen for the first time.

- Invalid: This tab appears if any installed plugins are corrupted or incompatible with the current version of QGIS. You can provide the developers consistent feedback by selecting a specific plugin from this tab and then clicking on the information about the potential invalidity that is displayed.
- Install from ZIP: Only when more recent versions of the installed plugins are accessible in the repository is this tab displayed.
- Settings: You can choose whether to utilize experimental or out-of-date plugins and choose how frequently updates will be checked on this tab. Although it is not advised to utilize experimental plugins in production, you can still select the option to view every tool that is offered. By default, only the *QGIS Official Plugin Repository* is linked, however you can add more repositories by selecting the Add... button if you are familiar with them. The previous graphic, for instance, demonstrates how to install an external Boundless plugin repository.

Core Plugins

Already included in the default QGIS installation are core plugins. You only need to enable them in order to use them. Many essential plugins are not always turned on. Plugins are loaded when QGIS starts up, therefore having a lot of plugins enabled can slow down startup. Disable all plugins you don't need for a better experience (QGIS.org, 2023c).

The core add-ons in the latest version of QGIS are (Fig. 7):

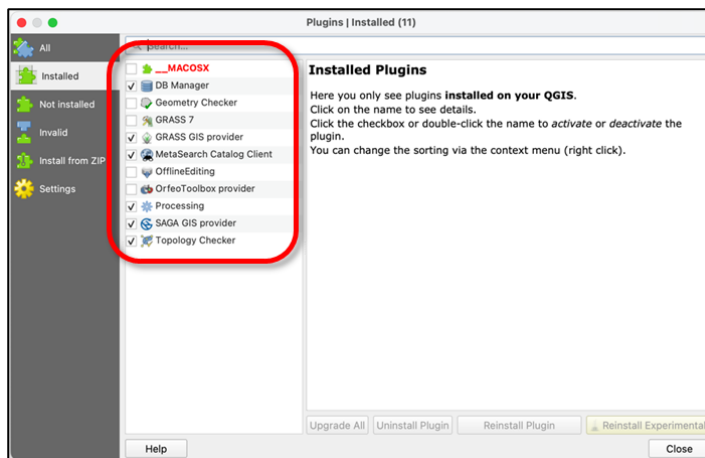


Figure 7. Core Plugins.

DB Manager : Manage your databases within QGIS. The primary tool for integrating and managing the spatial database formats offered by QGIS (PostGIS, SpatiaLite, GeoPackage, Oracle Spatial, Virtual layers) under one user interface is the DB Manager Plugin. Numerous functionalities are offered by the DB Manager Plugin. Layers can be imported into your spatial database by dragging them from the QGIS Browser into the DB Manager. The tables can be imported by dragging and dropping them between spatial databases.

- *Geometry Checker* : Geometry Checker is a powerful core plugin to check and fix the geometry validity of a layer. It is available from the “*Vector menu /  Check Geometries...”*. The *Geometry Checker Plugin* can find the following errors:
 - Self intersections: a polygon with a self intersection
 - Duplicate nodes: two duplicate nodes in a segment
 - Holes: hole in a polygon
 - Segment length: a segment length lower than a threshold
 - Minimum angle: two segments with an angle lower than a threshold
 - Minimum area: polygon area lower than a threshold
 - Silver polygon: this error comes from very small polygons (with small area) with a large perimeter
 - Duplicates features
 - Feature within feature
 - Overlaps: polygon overlapping
 - Gaps: gaps between polygons
 - *GRASS 7* : GRASS functionality
 - *GRASS GIS provider* : GRASS GIS Processing functionality
 - *MetaSearch Catalog Client* : Interact with metadata catalog services (CSW)
 - *Offline Editing* : Offline editing and synchronizing with database
 - *OrfeoToolbox provider* : OrfeoToolbox Processing provider
 - *Processing* : Spatial data processing framework
 - *SAGA GIS provider* : SAGA GIS Processing provider
 - *Topology Checker* : Find topological errors in vector layers. The relationships between the points, lines, and polygons that constitute a geographic region's features are referred to as topology. You can examine your vector files and check the topology using a number of topology criteria by using the Topology Checker plugin. These rules use spatial relations to determine whether your features are "Equal," "Contain," "Cover," "Covered By," "Cross," "Disjoint," "Intersect," "Overlap," "Touch," or "Within" one another. Which topological rules you apply to

your vector data depend on the specific issues you are trying to answer (for example, in general you wouldn't allow overshoots in line layers, but if they show dead-end streets you wouldn't remove them from your vector layer).

A built-in topological editing capability in QGIS is excellent for accurately constructing new features. However, user-caused and already-existing data inaccuracies are difficult to detect. Through a set of criteria, this plugin aids in the discovery of such problems.

External plugins

Although QGIS comes with a wide range of functions, there are a number of plugins that may be used to improve the program's performance and ease the handling of geospatial data (Free GIS Tutorial, 2023).

Users must install external plugins before utilizing them; they are available in the QGIS Plugins Repository. Following are some major categories into which external plugins can be divided (QGIS.org, 2023c).

- *GUI Plugins*: These plugins get installed to one of the “Menus or Toolbars”.
- *Processing Plugins*: These plugins will expand QGIS' "Processing toolbox" with new algorithms (i.e., tools). The preferred method for creating plugins that provide additional spatial analysis features is as described above. A processing toolbox algorithm can be used as a component of the model builder or in batch processing mode to automate GIS workflows as opposed to being a separate tool. Both new tools and menu items can be added via plugins.
- *Experimental Plugins*: Sometimes we are looking for a specific plugin, but cannot find it in the “All tab”. It may be because the plugin is marked “Experimental”. Experimental plugins are typically inappropriate for use in production. These plugins should be regarded as "incomplete" or "proof of concept" tools because they are still un the early phases of development. QGIS does not recommend installing these plugins unless you intend to use them for testing purpose (Fig. 8).

Exploring the QGIS Plugins Repository

The ecosystem of third-party plugins for QGIS is robust. More than 1900 plugins are available in the official QGIS plugin repository. New plugins that may be of interest to you can be found by browsing. Now let's look around the plugin archive.

Click "PLUGINS" in the menu bar of the "QGIS Plugins Repository" (<https://plugins.qgis.org/>) (Fig.9).

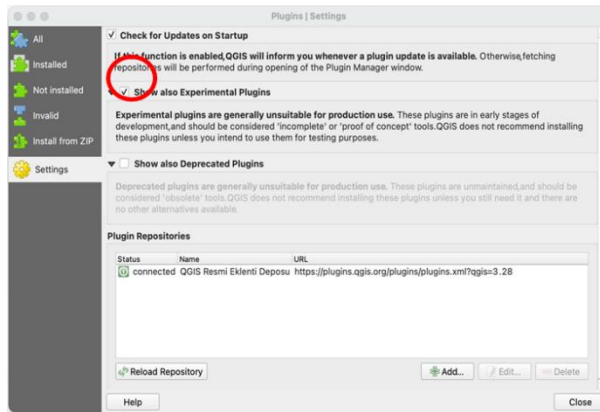


Figure 8. Experimental Plugins activate window.

There is a list of every plugin on this page. To arrange the plugins by various attributes, click the headings.

Additionally, there are many categories like Popular, Featured, etc. that make it possible to find fascinating plugins. All the most recent plugins will be fetched when you select New Plugins. You can choose any plugin you like.

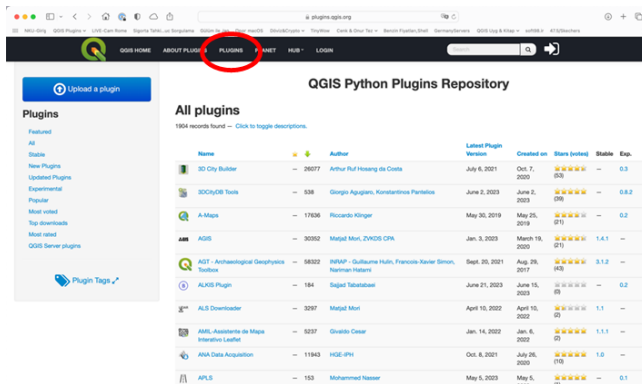


Figure 9. QGIS Python Plugins Repository webpage window.

Some of the most downloaded applications of QGIS are:

QuickMapServices

QuickMapServices is an essential plugin for QGIS that allows users to easily add base maps and other map services to their projects. This plugin provides access to a wide range of online map services, including OpenStreetMap, Bing,

Google, and more. It also allows users to add their own map services or WMS layers. The QuickMapServices plugin has been developed by NextGIS.

QuickMapServices

QGIS-OpenLayers-Plugin is a embedding OpenLayers functionality. It uses WebKit to render web based map services using their official Javascript API.

Semi-Automatic Classification Plugin

The Semi-Automatic Classification Plugin (SCP) allows for the supervised classification of remote sensing images, providing tools for the download, the preprocessing and postprocessing of images. Search and download is available for ASTER, GOES, Landsat, MODIS, Sentinel-1, Sentinel-2, and Sentinel-3 images. Several algorithms are available for the land cover classification. The plugin has been developed by Luca Congedo.

QuickOSM

QuickOSM is a QGIS plugin to download data from Overpass server.

QuickOSM allows to work quickly with OpenStreetMap data in QGIS thanks to Overpass API. OpenStreetMap represents physical features on the ground (e.g., river, lake, roads or buildings) using tags attached to its basic data structures (its nodes, ways, and relations). Each tag describes a geographic attribute of the feature being shown by that specific node, way or relation.

MMQGIS

This plugin is a collection of QGIS vector layer processing plugins. MMQGIS is a set of Python plugins for manipulating vector map layers in QGIS: CSV input/output/join, geocoding, geometry conversion, buffering, hub analysis, simplification, column modification, and simple animation. MMQGIS provides an alternative to the Processing toolbox, with verbose progress reporting, an intuitive user interface, direct shapefile/CSV-file access, and some additional capabilities missing from other plugin sets. Input layers can be from any geospatial data source supported by QGIS.

Output file format are implied by the file extension given on the output file name. Formats currently supported through OGR/GDAL include:

ESRI Shapefile (*.shp), GeoJSON (*.geojson), SQLite (Spatialite) (*.sqlite), KML (*.kml), GPKG (GeoPackage SQLite file)(*.gpkg)

Time Manager

Time Manager is a powerful plugin that allows users to animate temporal data in QGIS. This plugin is particularly useful for visualizing changes in data over time, such as climate data, population data, or land use changes. Time Manager allows users to create animated maps that show how data changes over a specific time period.

Qgis2threejs

3D visualization powered by WebGL technology and three.js JavaScript library. This plugin visualizes DEM and vector data in 3D on web browsers. You can build various kinds of 3D objects and generate files for web publishing in simple procedure. In addition, you can save the 3D model in glTF format for 3DCG or 3D printing.

Lat Lon Tools

Ttis plugin makes it easy to capture, zoom to coordinates, and interact with other on-line mapping tools. It adds MGRS, Standard UTM, and Plus Codes support to QGIS. When working with Google Earth, Google Maps or other on-line mapping tools, coordinates are specified in the order of 'Latitude, Longitude'. By default Lat Lon Tools uses the standard Google Map format, but is very flexible and can use virtually any projection and coordinate format for input and output. The plugin has the following tools.

These are just a few of the best QGIS plugins that can improve your analysis and display of geographical data. You may automate monotonous operations, optimize your workflow, and produce more interesting and instructive maps and visualizations by utilizing these plugins.

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