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## An Enhanced Tool for Visualizing and Analysing Geographic Information Systems

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### ABSTRACT

*3D Terrain Visualization is an area of research for visual analysis of geo-spatial data in a Geographical Information System (GIS). A GIS is a system of hardware and software for acquiring, storing, manipulation, visualization and analysis of geospatial data. GIS is used in many areas of application such as Rain Fall Study, Urban Town Planning, Route Finding, Oil Exploration, and Forest Conservation and so on. The rapid growth of GIS database imposes a real challenge to comprehend this data and extract any meaningful information. Data Visualization is one of the preferred methods for researchers to explore and make sense of this massive amount of GIS data. So, every GIS software is now equipped with visualization functionalities to do analysis on GIS data. The scope of our research work is to understand GIS and their Principles, Raster Data Analysis, Vector Data Analysis, Mapping and Display of terrain in three dimensions. The research is carried out using QGIS 3.4 software.*

*Keywords:— GIS, Terrain Visualization, QGIS*

## I. INTRODUCTION

3D terrain visualization of geographic information systems (GIS) data has become an important issue in recent years. This is due to the emergence of new geo-browsers such as Google Earth, widely popular among users. The availability of 3D representation tools has increased the demand for 3D terrain visualization. Terrain plays a fundamental role in modulating Earth surface and atmospheric processes. So strong is this linkage that understanding of the nature of terrain can confer understanding of the nature of these processes directly, in both subjective and analytical terms. Thus, analyses and representations of terrain have provided cardinal examples for many activities in GIS and environmental modeling. They have stimulated directly the development of new methods for obtaining digital environmental data new spatial interpolation methods and new methods for assessing data quality. Since 3-dimensionalrepresentations of terrain form natural back grounds for the display of spatially distributed quantities and entities, representations of terrain have also played a prominent role in the development of methods for conceptualization and visualization of3-dimensional data.

## II. METHODS

### 2.1 Contouring

Contouring has been the traditional way of presenting 3D terrain data on 2D sheets of paper. It has advantages of having units (contour values) so precise height calculations can be made. Contour lines are usually drawn with line segments so they

can easily be transferred to large scale hard copy devices such as plotters. The main problem with this visualization technique is that it does not give a good 3D impression of the terrain; the best most people can determine is that some localized parts of the surface are higher or lower than others.

## 2.2 Mesh Representation

This is the most straightforward way of rendering the 3D data; it is a direct perspective viewing transformation of the computer database. (Almost any 3D modeling package can display, view, and print this representation, Micro Station was used here due to its advantages when handling very large geometric databases).
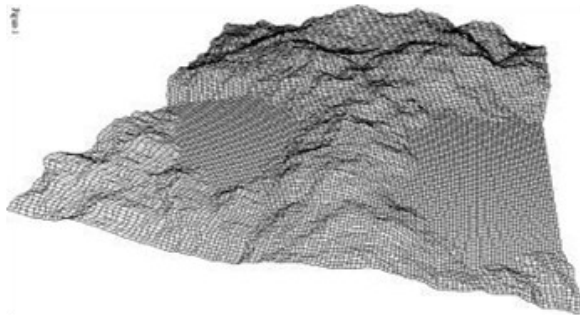


*Figure 1: Mesh Representation*

## 2.3 Vertical contouring

While horizontal contouring has long been a popular method, vertical contours can also be effective. The reasons for the success of this rendition method are the same as for mesh representations; it generates dark (dense) areas which would naturally be shadowed in direct sun light.

## 2.4 Shaded rendering

Higher levels of realism can be achieved by simulating more closely how the terrain would appear in reality. There are a wide range of techniques for accomplishing this, each technique generally involves a trade-off between realism and computation time.

## 2.5 Physical models

Given the digital model it is possible to determine the path required to manufacture the surface using a computer controlled milling machine. In its simplest form this is a drill which can be controlled backward and forward and up and down over a piece of wood say, so as to cut away unwanted portions.

## 2.6 Data reduction in terrain modeling

A common characteristic of terrain modeling/rendering exercises is the vast amount of data involved. This is particularly severe where the spot height information is a result of some automated survey or when it results from digitized contours. In addition there are a number of activities which require very different levels of detail, for example the detail required for high quality renderings may be quite high. The information that a 3D modeling package can handle while retaining user interaction may be quite low. The need for multiple terrain representations can arise naturally in modeling applications, for example it may be necessary to acquire a more course terrain model for interactive modeling and substitute a more detailed version for final presentation. As with many computer based activities there is often a gap between what one might like to and what is practical given disk, memory, or processing resources. There are two common representations for computer based terrain models. The first consists of a triangular mesh of polygons; this is normally the result from a triangulation process. One advantage of this approach is that it naturally generates detail in the regions that are sampled more frequently; these are normally the regions which have more height variation. This representation is a more faithful representation of the underlying data since the sample points are

generally the vertices of the triangular mesh.

The second form of representation is as a regular mesh of rectangular polygons, these are generated by estimating the heights at each corner of the mesh cells. The main advantage with this is that multiple resolution meshes can be readily generated from the same dataset of spot heights. This form is tend to provide more 3D visual cues as the wire frame rendered mesh acts a type of slope based shading.

## 2.7 Real time and non-real time approaches

3D terrain visualization can be divided into two types; real-time visualization and non-real time visualization. Many techniques have been introduced by researchers in order to achieve the real-time terrain visualization in 3D. For example, research on reducing the size of terrain data by using compression techniques. They used a second generation wavelet with a lifting scheme algorithm to reduce the data-set size for efficient online transmission of terrain data. In the techniques which are not real time, pointed out the importance of data structures for 3D terrain visualization providing algorithms for efficient access to the visible portion of data needed to render each frame.

## III. GEOGRAPHIC INFORMATION SYSTEM

### 3.1 Overview

A geographic information system (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data. GIS applications are tools that allow users to create interactive queries (user-created searches), analyze spatial information, edit data in maps, and present the results of all these operations. GIS sometimes refers to geographic information science, the science underlying geographic concepts,

applications, and systems. In simple way GIS can be define as an image that is referenced to the earth or has x and y coordinate and its attribute values are stored in the table. These x and y coordinates are based on different projection system and there are various types of projection system. Most of the time GIS is used to create maps and to print. To perform the basic task in GIS, layers are combined, edited and designed.GIS can refer to a number of different technologies, processes, techniques and methods.GIS can relate unrelated information by using location as the key index variable. Locations or extents in the Earth space–time may be recorded as dates/times of occurrence, and x, y, and z coordinates representing, longitude, latitude, and elevation, respectively.GIS data represents real objects (such as roads, land use, elevation, trees, waterways, etc.) with digital data determining the mix. Real objects can be divided into two abstractions: discrete objects (e.g., a house) and continuous fields (such as rainfall amount, or elevations). GIS can be used to solve the location based question such as "What is located here" or Where to find particular features? GIS User can retrieve the value from the map, such as how much is the forest area on the land use map. This is done using the query builder tool. Next important features of the GIS are the capability to combine different layers to show new information. For example, you can combine elevation data, river data, land use data and many more to show information about the landscape of the area. From map you can tell where a high land is or where is the best place to build house, which has the river view.GIS helps to find new information.

### 3.2 How GIS works

❍ *Visualizing Data:* The geographic data that is stored in the databases are displayed in the GIS software.

❍ ***Combining Data:*** Layers are combined to form maps of desire.

❍ ***The Query:*** To search the value in the layer or making geographic queries.

## 3.3 Advantages of GIS

❍ Improve decision making with the help of layered information.

❍ Help to identify communities that are under risk or lacking infrastructure.

❍ Better management of natural resources. Cost savings due to better decision

❍ Finding different kinds of trends within the community. Planning the demographic changes.

### 3.4 GIS data types

### 3.4.1 Vector data

Vector data is arguably the most common kind of data you will find in the daily use of GIS. It describes geographic data in terms of points that may be connected into lines and polygons. Every object in a vector dataset is called a feature, and is associated with data that describes that feature.

### 3.4.2 Raster data

Raster data in GIS are matrices of discrete cells that represent features on, above or below the earth's surface. Each cell in the raster grid is the same size, and cells are usually rectangular (in QGIS they will always be rectangular). Typical raster datasets include remote sensing data, such as aerial photography, or satellite imagery and modeled data, such as an elevation matrix.

Unlike vector data, raster data typically do not have an associated database record for each cell. They are decoded by pixel resolution and the x/y coordinate of a corner pixel of the raster layer. This allows QGIS

to position the data correctly in the map canvas.

QGIS makes use of geo reference information inside the raster layer (e.g., GeoTiff) or in an appropriate world file to properly display the data.

❍ Continuous rasters are grid cells with gradual changing data. For example, digital elevation models (DEM) and temperature data are continuous raster data.

❍ Discrete rasters have distinct themes or categories. For example, land cover has discrete classes with clear boundaries. One grid cell represents a land cover class.

### 3.5 GIS components

❍ ***Hardware:*** Hardware is the physical component of the computer and GIS runs on it. Hardware may be hard disk, processor, and motherboard and so on. All these hardware work together to function as a computer. GIS software run on these hardware. Computer can be standalone called desktop or server based. GIS can run on both of them.

❍ ***Software:*** GIS Software provides tools and functions to input and store spatial data or geographic data. It provides tool to perform geographic query, run analysis model and display geographic data in the map form. GIS software uses Relation Database Management System (RDBMS) to store the geographic data. Software talks with the database to perform geographic query.

❍ ***Data:*** Data are the fuel for the GIS and the most important and expensive component. Geographic data are the combination of physical features and its information which is stored in the tables. These tables are maintained by

the RDBMS. The process of capturing the geographic data is called digitization. It is the process of converting scanned hardcopy maps into the digital format. Digitization is done by tracing the lines along the geographic features for example to capture a building you will trace around the building on the image.

## III. QGIS

QGIS (previously known as Quantum GIS) is a free and open-source cross-platform desktop geographic information system (GIS) application that supports viewing, editing, and analysis of geospatial data.

QGIS functions as geographic information system (GIS) software, allowing users to analyze and edit spatial information, in addition to composing and exporting graphical maps. QGIS supports both raster and vector layers; vector data is stored as point, line, or polygon features. Multiple formats of raster images are supported and the software cangeoreference images.

QGIS integrates with other open-source GIS packages, including PostGIS, GRASS GIS, and Map Server. Plugins written in Python or C++ extend QGIS's capabilities. Plugins can geocode using the Google Geocoding API, perform geoprocessing functions similar to those of the standard tools found in ArcGIS, and interface with PostgreSQL/ Postages, SpatiaLite and MySQL databases.

We can add several data related to a particular region in QGIS. The data are added in the form of layers in this software. Depending on their features of data, several layers are added, containing similar information. The layer files have the extension .shp.

A shape file actually consists of several files. The following three are required:

- ❍ .shp file containing the feature

geometries
- ❍ .dbf file containing the attributes in dBase format
- ❍ .shx index file

Shape files also can include a file with a .prj suffix, which contains the projection information. While it is very useful to have a projection file, it is not mandatory. A shape file dataset can contain additional files.

### 3.1 Vector data operations

### 3.1.1 Single theme

### A . Node point:

Creates a new point theme from the nodes of arc.

Imagine a road theme as shown in Figure (a) having road feature- a line theme where nodes are present at locations where two or more roads meet. At these intersections lie the traffic light poles. Now if one only wants to see the location of traffic lights in the area, he/she can use the Node point to extract the point theme from the nodes of the line theme to represent the location of traffic light poles.

### B. Buffer

A buffer is a zone with a width created around a spatial feature and is measured in units of distance from the feature. The generated buffer takes the shape of the feature. In case of a point the buffer is a circle with a radius equal to the buffer distance. In case of a line, it is a band and for a polygon it is a belt of a specific buffer distance from the edge of polygon, surrounding the polygon. The inward buffer for a polygon is called Buffering is used for neighborhood analysis which aims to evaluate the characteristics of the area surrounding the spatial feature. Common

examples of buffering include the identification of properties within a certain distance of an object, delineation of areas around natural features where human activities are restricted, determination of areas affected by location etc.
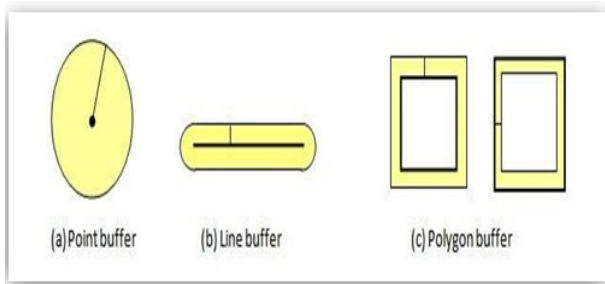


*Figure 2 : Buffer*

## C . Dissolve

It merges the adjacent features if they have the same attribute value and reduces the records from the attribute table.

Let us understand it through following examples

Type is used as the dissolve item.

### 3.2 Multiple theme

These operations work on the layers at a time rather than selective spatial features. The layers which are used must be topologically structured so as to get a correct, topologically structured output.

### A. Clip

Clip is used to subset a point, line or a polygon theme using another polygon theme as the boundary of the area of interest.

In the illustration above, the input, point feature shows the location of drinking water wells in three villages. To know how many wells fall in village1, the input feature class is clipped using the boundary of the village1. The output feature class shows that five wells are present in village1.
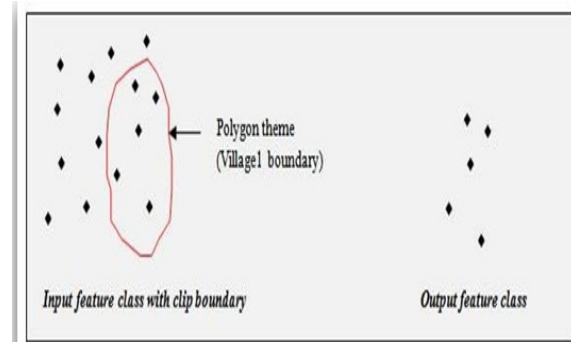


*Figure 3: Clip*

## B. Split

Spilt causes the input features to form subset of multiple output feature classes. The split field's unique values form the names of the output feature classes.

In the illustration above, a point theme of wells is split using the polygon theme of watershed boundaries. The output of this operation contains multiple feature classes which are named on the unique value of watershed boundaries (in this case, the unique value is the watershed number WS1, WS2 etc.). Each output class represents the number of wells present in a particular watershed i.e. WS1 or watershed 1 has three wells. Similarly, WS2, WS3 and WS4 have 3, 2, and 2 wells respectively.
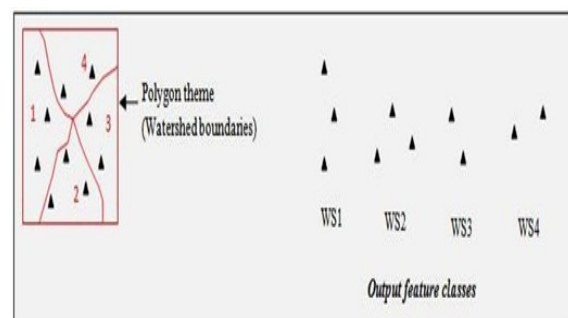


*Figure 4: Split*

## C. Union

Union creates a new theme by overlaying two polygon themes. It is same as 'or' Boolean operator. The output theme contains the combined polygons and attributes of both themes. Only polygon themes can be combined using union.

### D. Intersect

Intersect creates a new theme by overlaying a point, line or polygon theme with an intersecting polygon theme. It is same as 'and' Boolean operator. The output theme contains only the feature inside the intersecting polygons.

### E. Identity

Identify creates a new theme by overlaying a point, line, or polygon theme with an intersecting polygon theme. The output theme contains all the original point, line, or polygons as well as the attributes transferred by the intersecting polygon theme.

### F. Erase

Erase removes polygons in a theme from the area covered by polygons of another theme. The output feature class only contains those features of the input polygon theme that fall outside the polygons of the second theme.

### 3.3 Raster data operation

### 3.3.1 Local Operation

Local functions process a grid on a cell-by-cell basis, that is, the output value of each cell depends on the values of corresponding cells in the rasters input for the analysis. The following are the examples of the local operations.

### 3.3.2 Arithmetic Operation

Grids can undergo a range of arithmetic operations such as addition, subtraction, multiplication, and division. If the data in grids (operands) is in the form of integer then the data in the resultant grid after any mathematical operation would also be integer.

Only in one case, when any integer is divided by zero the corresponding resultant cell will be undefined and are assigned to no data. No data cells always remain No data in arithmetic operations.

### A. Select

Select returns original cell value if the cell meets the logical expression criteria otherwise the output cell is assigned no data.

### B. Test

Test performs a Boolean evaluation of the input raster using a logical expression. If the cell meets the logical expression criteria it assigns the output cell a value of 1 otherwise the output cell is assigned 0.

### C. Con

Con performs a conditional evaluation on each cell of the input raster. It tests for a user specified logical expression and return user specified values.

### 3.3.4 Focal Operation

The value of a cell in the output raster depends upon the value of the corresponding cells and their neighboring cells in the input rasters. The neighborhood for a cell is generally taken as a 3×3 matrix (window) in which the cell itself occupies the centre and is surrounded by the others eight cells. With each cell in the input getting processed, the neighborhood window keeps moving.

### A. Spatial Aggregation

It is the process of reducing the number of cells in the raster layer to achieve generalization. It is not a compression technique because the same geographic space is represented using small number of cells of coarse spatial resolution. The

choice of neighborhood window size results in different outputs. A large window size will result in higher aggregation level which implies a greater loss of details.

A user can use one of the following aggregating methods:

- ○ *Averaging method:* It compute average value of the cells over the window and is used as the value of the aggregated cell.

- ○ *Central cell method:* Value of the cell at the centre of the window is the value of the aggregated cell.

- ○ *Median method:* It computes the median value of all the cells over the window and uses it as the value of the aggregated cell.

## B. Filtering

Filtering is used to enhance an image. The value in each cell of the raster image indicates the degree of brightness at that point. The change in brightness value per unit distance for any part of the image gives rise to an image characteristic called spatial frequency. If the change is small, the area is of low frequency and if the brightness values change rapidly over small distance the area is of high frequency. The method of filtering uses a filter window or kernel (generally a 3×3 matrix) which is passed over the whole image. On passing the kernel over the image, the coefficients in the kernels are multiplied by the value of the corresponding cells and the average value is assigned to the cell at the centre of the kernel.

Filtering suppresses noise in the image and highlight specific characteristics.

## 3.3.5 Zonal operation

Zonal functions process grid in such a manner that cells of same zone are analyzed together. A zone may or may not be contiguous. The output value for each location depends upon the value of cell at that location and the association the location has within a zone.

### A. Zonal Geometry

The zonal geometric functions return geometric information about each zone in a grid. Following geometries can be calculated using it.

*Area:* For each zone in the input raster, Zonal area calculates the area and assigns it to each cell of the zone on the output raster. The area is calculated by the number of cells that comprise the zone multiplied by the current cell size.

*Perimeter:* Zonal perimeter determines the perimeter of each zone on the input raster and assigns it to each cell in the zone on an output raster.

*Centroid:* Zonal centroid approximates the geometry of each zone by creating an ellipse fixed at the centroid of each zonal spatial shape. The area of each ellipse is equal to the area of the zone it represents.

*Zonal Statistics:* It calculates statistics for each zone of the input dataset. The zonal statistical functions return a statistical measure of the values of each zone. The measure can be the mean, median, majority, standard deviation, sum, minimum, maximum, or range of the input values.

### 3.3.6 Global Operation

The value of each cell in the output raster is a function of the entire grid. Following are few of the global functions:

### A. Region Group

It aggregates the cells with same values into groups. It starts at upper left corner cell and proceed left to right assigning group

numbers based on cells that touch and have the same cell values.

The value attribute table contains link along with the values and their count. Link is the original value of the cells before the grouping occurred.

## B. Euclidean Distance

The Euclidean distance grid identifies the distance from each cell to the closest source cell.

The output values for the Euclidean grid are floating-point distance values. If a cell is at an equal distance from two or more sources, it is assigned to the source that is first encountered in the scanning process (The process of scanning starts at the upper left corner and moves from left-to-right, top-to-bottom).

Other global functions include Cost distance, Cost path, Eucdirection, Slice etc

## IV. CONCLUSION

Since the earliest map produced until now, rapid changes in the technology have occurred especially in the preparation of reliable 3D terrain visualization for GIS applications. 3D terrain visualization plays an important part in developing the GIS related applications such as 3D city models, urban visualization, town planning, tourism, military, and many more. 3D terrain visualization involves processing large terrain datasets. There are many problems to solve due to the large size of terrain data. Since terrain visualization is not limited to the earth, recent discoveries in space science reveal the need to use terrain visualization for extraterrestrial planets.GIS is a system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data.GIS is richer for the demands of spatial data analysis, and spatial data analysis is richer for the focus

that GIS has brought to issues of representation.GIS is in many ways the result of adapting generic technologies to the particular needs of spatial data. QGIS is widely used industry-grade open source GIS software. QGIS functions as geographic information system (GIS) software, allowing users to analyze and edit spatial information, in addition to composing and exporting graphical maps. QGIS supports both raster and vector layers; vector data is stored as point, line, or polygon features. Multiple formats of raster images are supported and the software can handle geo-reference images. The underlying plug-in architecture of QGIS allows it to extend the features of the software.

In this paper, we have investigated terrain visualization using the QGIS software. We have explored all the features of the software. We have experimented the software with publicly available terrain datasets. We have studied vector and raster data using QGIS software and also changing the symbology of both raster and vector layers. The contouring features for the datasets are also explored. We have also studied and analyzed the plug-in architecture of the software. We have implemented a plug-in in python and added to QGIS software.

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