Principles for accomplishing the digital model of the terrain

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Abstract: *The digital model of an object or phenomenon is constituted of a data collection systematically stocked (data base) that describe a tri-dimensional system of coordinates, arbitrary or particularly can form the object features or states/accomplishments of the phenomenon (conversion as a digital image) and allow by calculation programs, deducting the object or states shape and features for the phenomenon in new points.* ***Modelling the areas*** *is the process for representing graphically a natural or artificial area by using one or more mathematical equations.* ***Modelling the terrestrial area*** *is a particular case for modelling an area where we should take into account the specific problems for representing the Earth or some of its parts.*

Keywords: *digital model , Modelling, terrain, DTM, Data acquisition*

1. Introduction

From the fields where the digital model can have an immediate applicability are as follows: analyse of telecommunication systems, designing the pipe networks (water pipes), command and control of different systems, as in all other fields where it is necessary to know the altitude information in different points of an area.

The term of ***„digital terrain model"*** was used for the first time in 1958 by Miller and Laflamme who defined it as "a statistic representation of continuous area by using a great number of points whose horizontal coordinates (x, y) together with the altitude (z) are known and this representation is made in an arbitrary coordinates system".

The digital terrain model represents an informatics' instrument composed by terrain data and software that represent a basic component of a GIS.

The digital terrain model (DTM) is composed by 3 sub-systems:

1. Digital elevation model- DEM contains altitudes, slopes, curves, etc.
2. Digital planimetric model – DPM contains planimetric data and elements.
3. Digital model of objects nature – DEN contains pedologic, geologic, hydrologic data etc.

2. Principle of accomplishment

DEM are tools very necessary in almost any type of analyse or modelling so that it can be considered the most important sub-system from the digital terrain model.

The digital elevation model (DEM) represents the starting point for calculating some morphometric elements of the relief and making the digital geo-morphological maps and also for spatial and mathematical analyse, methods specific for GIS in order to solve some theoretical and practical problems of geography and not only of it.

DEM is constituted of an order of information regarding the planimetric position and altitude of some points that describe the configuration of spatial development of relief structures and facilitates to be rebuilt their area in new points.

An DEM describe an area by using a function z=f(x,y), so for a position of x,y from the field can be determined by a single value of z.

2.1. Stages of making a DTM

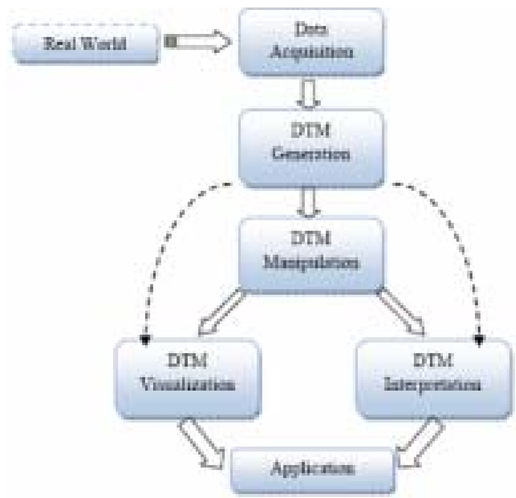

Fig. 1 Principle of making a DTM

For elaborating a digital terrain model and using it in the future has the following stages:

1. **GENERATING A DTM** that consists in supplying initial data and building the digital model. This stage represents an important phase because the existence of the errors introduced in the stage of supplying the data will exist also in DTM and will commit the whole process of spatial analyse.
2. **MANIPULATING THE DTM**: correcting the errors and updating the model, filtrating operations, combining more models come from different sources or periods, transforming the model structure (TIN – raster and vice versa);
3. **INTERPRETING THE DTM**: analysing the model and extracting the useful information;
4. **VISUALISING THE DTM**: graphic presentation of DTM (2D representation, 3D representation, animation, etc.), this stage being linked to the previous one;
5. **EXPLOITING THE DTM**: developing the specific applications for the wanted field.

Generating the DTM refers to **the way of data acquisition**, to making the model by using different **interposing methods** and also **choosing the structure of data representation (raster or TIN)**.

Data acquisition represents the process to be obtained the data from an exterior source of GIS and transforming them in a specific digital form.

It can be met three main groups of **data acquisition methods** as follows:

✓ **Photogram metric methods** based on using the analogical equipments and digital photogram metric stations. There are used for the great/average scale projects. The error increases once with fragmenting the relief and with the slope.

- **Advantages:**
  - the data are obtained very easy and it allows to obtain some DTM very precisely;
  - the possibility of eliminating the redundant data in the moment of data acquisition, their density being able to be adapted to the complexity of the relief;
  - there can be obtained some data also for the regions for which the other methods cannot be applied (areas for which there are no topographic maps, areas where the access is forbidden due to some political or military causes and areas with very difficult terrain).
- **Disadvantage:**
  - price that, even if it is smaller than the one of a topographic survey for the same surface, remains still big for many users;
  - data precision which can be different depending the relief of terrestrial surface: the errors are greater for the mountain areas that represent great vibrations of morphometric values (especially the slope) in comparison with the field areas.

✓ **Topographic methods** based on using total stations. They are used for small scale projects. This method cannot be applied for very difficult areas.

- **Advantage:**
  - allow to be obtained some very exact data used for obtaining some precise models;
  - it can be surprised in detail the “key elements” of the relief (abrupt areas, picks) which lead to increasing the quality of terrain representation;
- **Disadvantage:**
  - long time – to make the topographic surveys – in spite of modern equipments – and possibility of using this method only for small areas;
  - very difficult of being used (sometime even impossible) in difficult areas (mountain areas) or where the access is forbidden (for example military conflicts).

A particular case of this method consists in making the **topographic surveys** by using GPS that is an economical alternative of the classic topographic surveys.

- **Advantages:**
  - by using modern equipments it can be obtained good data that lead to obtaining some great accurate MNT;
  - it is the possibility to memorise a great number of data and even of GPS connection to PC for downloading the data direct into GIS.
- **Disadvantage:**
  - this method can be applied also for small areas;
  - the GPS can be used only for open areas. For the forests, valleys, near mountains, into the caves and near the buildings the satellite signal is small and GPS receivers cannot be used.

✓ **Digitising methods** of the cartographic products where the level curves on the maps and plans are transformed in files of planimetric coordinates (x,y) and altitudes (z).

- **Advantages:**

• maps on papers are very used, they are cheep and they have a different scales;

• the existence of printed maps in different periods of time allows for the same territory to be studied in evolution perspective;

• the existence of many thematic maps, which, even are not used for MNT, can be very useful for a morphologic analyse by using SIG.

- **Disadvantage:**

• the level curves represent values from the initial set of data extracted from the field. For obtaining a MNT there are used a second interposing (between the level curves), so it is explained the small precision of digital model;

• producing some errors in the moment of digitising the level curves;

• concentrating the data along the level curves and their absence between the curves;

• lack of data in case of picks, rock areas, chine;

• the topographic maps do not surprise enough elements of detail in order to be used for making very precise digital models necessary in simulation processes where it is needed supplementary data.

If we do not have this kind of supplementary information we can consider that the slope between the two level curves increases or decreases uniform that leads to uniforming the relief into the spaces between the isolines.

Building the model consists in creating a continuous area by using the interposing method starting with the data collected from the field by using one of the above mentioned methods.

There are no universal algorithm of interposing good for all applications and each method has a series of advantages and disadvantages.

Many times the user is forced to choose a method taking into account the methods put under his disposal by the GIS manufacturer.

2.2. Classification of interposing methods

- **Depending on the grade of altering the initial data:**

- **exact** (when the obtained model keeps the values of initial data);
- **inexact** (when the initial values are altered).

- **Depending on the number of values taking into calculation:**

- **global,** which use all the values simultaneously;
- **local** when in order to calculate the new values there are used only the known values from the neighbourhood.

The algorithms of interposing used for generating a DTM are usually exact and local.

Linear interposing is one of the methods used for obtaining a DTM of raster type by using level curves of a topographic map. The quality of this model has evident errors. The histogram of such model has a laced surface, with many picks correspondent to the values of the level curves which proves that the data have a greater density along the isolines than in the space between them, this model having the “mark” of initial topographic map.

3. Accuracy of Digital Terrain Models

The quality of digital terrain models is determined by how accurate the pixel values (in case of a DEM) or its equivalent in other models is. The accuracy of DTMs is a function of a number of variables:

- terrain roughness
- accuracy of data source
- method of data acquisition
- sampling density
- interpolation algorithm
- vertical resolution

4. Example of generating a DTM for the Jiu Valley Mining Basin

A *contour plot* (Fig. 2) connects points having some features (climatic, geographic, economic, etc.) in common. These are also known as *isolines, isograms or isopleths*. Mathematically, a contour connects two points where a function has the same value for both the points i.e. given a value *z*, the contour plot connects the point *x, y* provided the *z*-value occurs at both. This can be used for 2D representation of 3-D surfaces.

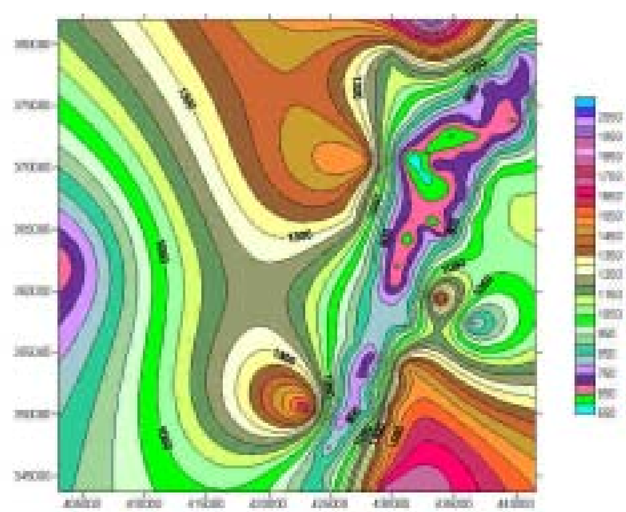

Fig. 2 The Site-level curves

The interposing methods type triangulation one after whom it is obtained a TIN structure **(Triangular Irregular Network)** (Fig. 3)**,** are also multiple. The best one is ***Delaunay Interposing*** that allows to be obtained some perfect triangles inside a circle so the distance between the points from the picks of the triangle is always minim.

For each triangle there are memorized the coordinates and attributes of the three picks, topology and slope and declination direction of the triangle surface.

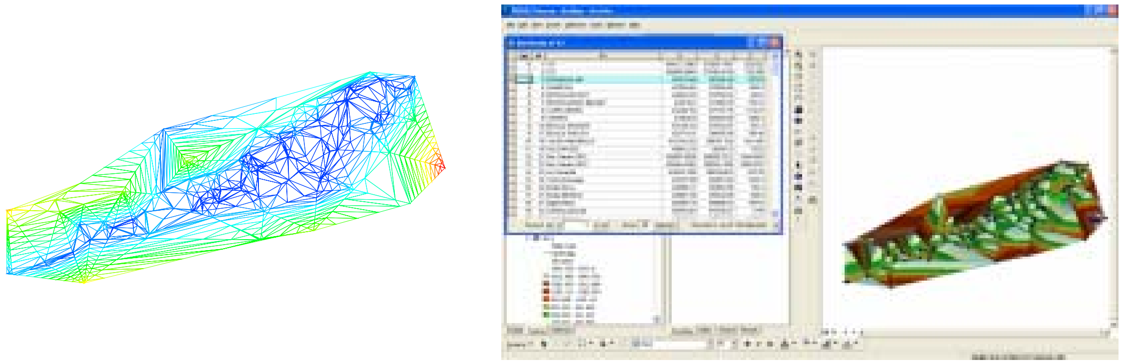

Fig. 3 Elaboration of TIN structure

Three dimensional visualization (Fig. 4, Fig. 5) is the preferred way of visualization to comprehend the actual terrain of any place. This can be achieved by techniques using wire frame models or rendering from a 3-D plane to a 2-D plane. For added realism, image based information is added to the rendered primitives. This kind of texture mapping serves to increase the visual appeal and increase the vivid detail. This is popularly known as *draping*, and leads to a greater understanding of patterns in the image and how they relate to the shape of the earth’s surface.

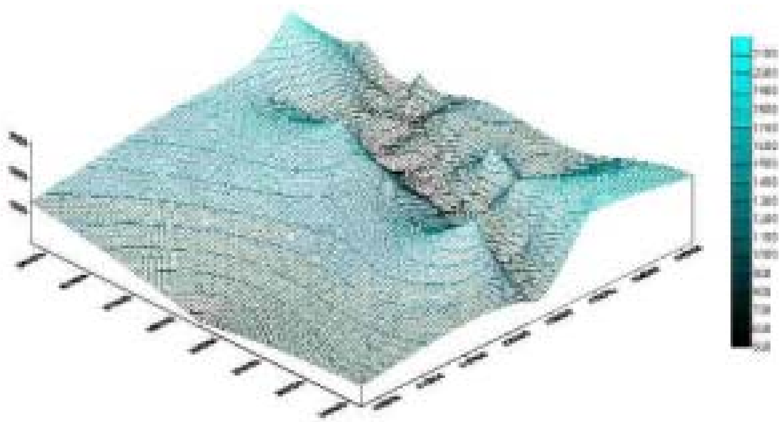

Fig. 4 The 3D Wire frame model

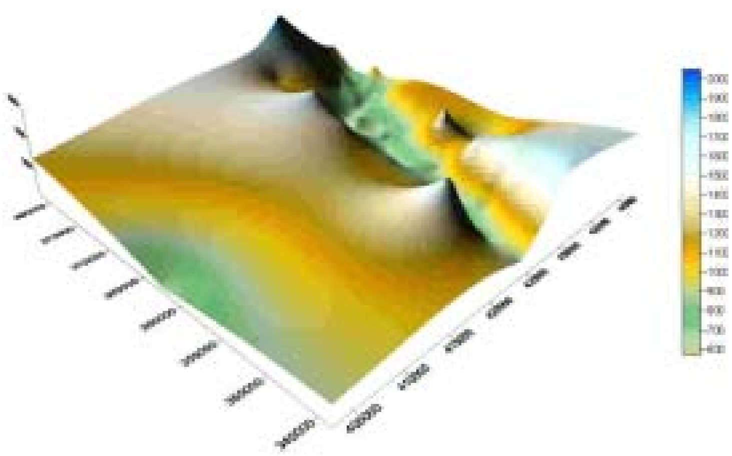

Fig. 5 The 3D Surface model

5. DTM Interpretation

The analysis of DTMs to extract terrain parameters is termed DTM interpretation. The extraction can be performed by either visual analysis (using visualization techniques, discussed in the next section) or quantitative analysis (interpretation). The analysis can be grouped into *general geo-morphometry* or *specific geo-morphometry*. General geo-morphometry deals with quantification of general surface characteristics such as slope, gradient or aspect.

The concept of measuring slope from a topographic map is a familiar one for most professionals in the landscape planning/surveying professions. Slope is a measurement of how steep the ground surface is. The steeper the surface the greater the slope. Slope (Fig. 6) is measured by calculating the tangent of the surface. The tangent is calculated by dividing the vertical change in elevation by the horizontal distance. If we view the surface in cross section we can visualize a right angle triangle:

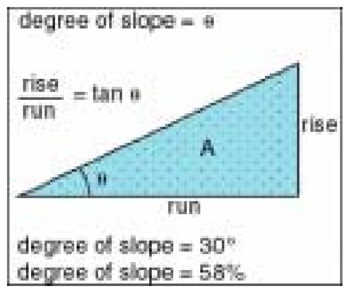

Fig. 6 Slope

Slope is normally expressed in planning as a percent slope which is the tangent (slope) multiplied by 100.

Percent Slope = Height / Base * 100

This form of expressing slope is common, though can be confusing since as 100% slope is actually a 45 degree angle due to the fact that the height and base of a 45 degree angle are equal and when divided always equals 1 and when multiplied by 100 equals 100%. In fact slope percent can reach infinity as the slope approaches a vertical surface (the base distance approaches 0). In practice this is impossible in a gridded database since the base is never less that the width of a cell.

S*lope* is an attribute to define surface and comprises gradient and aspect. When written in the form of a mathematical equation g*radient* (usually calculated in degrees) refers to the first vertical derivative of altitude and represents the rate of change in its magnitude over distance. Similarly a*spect* is the first horizontal derivative of the altitude and represents the direction of the slope . The formulae for calculation of slope are mentioned below:

$$Gradient = \sqrt{\left(\frac{\Delta z_x}{\Delta x}\right)^2 + \left(\frac{\Delta z_y}{\Delta y}\right)^2} \qquad Aspect = \tan^{-1}\left(\frac{\frac{\partial f}{\partial x}}{\frac{\partial f}{\partial y}}\right)$$

The curvature (convexity / concavity) of the terrain can be determined by the second order derivatives. Curvature of the surface helps define the movement of masses.

$$Curvature = \sqrt{\left(\frac{\partial^2 f}{\partial x^2}\right)^2 + \left(\frac{\partial^2 f}{\partial y^2}\right)^2}$$

General geo-morphometric analysis finds use in computation of relief, visibility analysis, flow acceleration, and drainage density calculation.

Specific geo-morphometric analysis defines the geometry and topology of specific features. Point, line, and area features such as peaks, pits, ridges, channels, and basins are identified and topologically connected this way. A widespread example of this is in the computation of hydrological terrain parameters. These help in estimations such as calculation of flow of objects such as water between land units. The flow direction, drainage networks, flow accumulation, catchments areas to name a few parameters can be calculated this way.

6. Conclusions and proposals

Many of the uses of DTMs are implicit in their modelling and interpretation techniques. As previously discussed, DTMs find wide use in ecological and hydrological applications, such as the computation of hydrological parameters to model water flow in a terrain. A *watershed* is used for this purpose in order to determine the catchments area, by identifying the steepest downhill path extending from an area of interest. Other common applications are the development of soil erosion models, glacial modelling, landslide prediction, catchment’s and drainage network analysis. Risk assessment of avalanche and fires are other highly critical applications in which DTMs are can be used. Identifying areas having a high risk of fire by also take into consideration various conditions such as wind direction, amount and type of vegetation and steepness of slopes. Civil engineering applications of DTMs include highway and railway design. Other than these, they are also used in military applications, flight simulators and interactive computer games.

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