DIGITAL SURFACE MODELLING: APPLICATIONS IN THE SUGAR INDUSTRY

By M. G. WALLACE

South African Sugar Association Experiment Station, Mount Edgecombe

Abstract

A digital terrain model (DTM) is a representation of surface relief encoded in a format which can be analysed by computer. DTMs can be created using any data set which consists of a number of geographical co-ordinates with an elevation or quantity attached to each position. Data which have been represented in this way are topography, meteorological statistics (e.g. rainfall, evaporation and temperature) and soil analysis. Other areas where the use of DTMs in data analysis could be useful are suggested. The process involved in creating the DTM is discussed. The DTM can then be analysed by interpolation of contours at the desired scale, by interrogation at a specific point using the computer's cursor, or by producing a perspective view three dimensional (3-D) drawing. The Farm Planning department of the South African Sugar Association Experiment Station (SASEX) uses the SURFACE module of their UNIGIS Geographic Information System for producing and analysing DTMs. Analyses in the land use planning environment are carried out with software specifically written for SASEX.

Introduction

A digital terrain model (DTM) is a representation of the shape of a surface in a format suitable for a computer. If a giant imaginary fishnet were thrown over a landscape and then starched rigid, when removed it would retain the shape of the land. Each intersection of the net would represent a grid reference - the x and the y co-ordinates. Its elevation would be the z value. Between the intersection points the computer uses survey techniques to interpolate slopes (Figure 1).

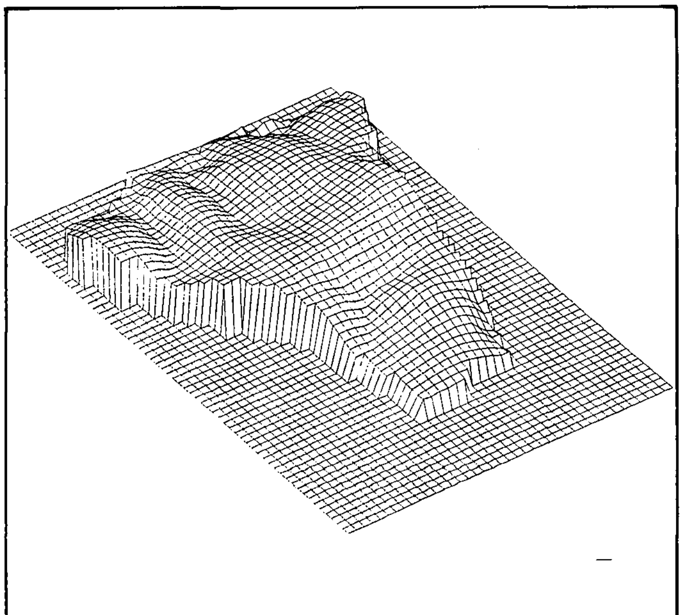

FIGURE 1 Perspective view of a digital terrain model.

The z value can be an elevation or any value which can be measured at a specific point, e.g. climatic data, soil nutrients or pest and disease attributes. If, for example, mean annual rainfall were used, the net would represent rainfall distribution and would usually be displayed as rainfall contours (isohyets).

Method

Hardware

The minimum requirements are a personal computer (PC) and a plotter or printer able to produce a drawing. The mathematics used to process DTMs involve complex routines, and with an AT 286 the processing of farm-sized DTMs takes several hours. With the faster 386 and 486 machines the processing time can be reduced to less than an hour for the same sized DTM.

Software

The Farm Planning department obtained the software to construct and analyse digital terrain models as part of their Geographic Information System (GIS) package (Platford, 1990). The SURFACE suite of programmes was written by a local company and customised for use by SASEX. While the primary use of this package is in land use planning it has been used for various other applications.

The process

The computer requires a list of x, y and z co-ordinates in a specific format from which to create a DTM. If the DTM is of a grid survey of a field, this would simply be a grid reference from a bench mark in the field (the y and x co-ordinates) and the reduced level at each point (the z value). For example, on a 50 m grid the co-ordinates may be similar to those below:

y	x	z
00	50	4,51
50	00	4,63
100	50	4,77
150	50	5,83 etc.

A model with a continuous grid is formed from the data. This is the digital terrain model which can then be used to calculate co-ordinates and elevation at any point within the grid. Contours can be generated at specific intervals or a 3-D perspective diagram can be prepared.

Applications

Land use planning

The surface model has been used by the Farm Planning department in preparing land use plans and grid surveys. The layout of field boundaries, siting of terraces and extraction roads and their gradients are all largely determined by the prevailing slope or topography. Recent development work for small cane growers in KwaZulu has required slope analyses over large areas, to extract parcels of land which conform to government criteria regarding slope. These operations are ideal applications for computer analysis with DTMs.

The topographic data from which the DTM is created can be obtained in various ways; either existing contour lines are digitized, which involves physically tracing over the contours (usually from orthophotos) with electronic equipment, which encodes and copies the lines into the computer; or the data are obtained in digital format from the Surveyor General or from the air survey companies. The latter method is preferable as digitizing contours is a time consuming exercise. Unfortunately such digital data are difficult to obtain at a density suitable for farm planning operations and, where suitable data are available, they are usually very expensive to acquire.

Alternatively, the area to be modelled could be surveyed in the field - particularly where more accuracy is required than can be obtained from orthophoto contours, which are at a scale of 1:10 000.

Once the required data are assimilated and processed the resulting DTM can be used to interpolate contours and analysed for the following:

Slopes: slope classes can be extracted according to required parameters and arrows inserted to show slope direction. Different slopes are usually represented by different colours or, as shown in Figure 2, by different symbols where colour is not available. The areas of the different slope classes can then be calculated.

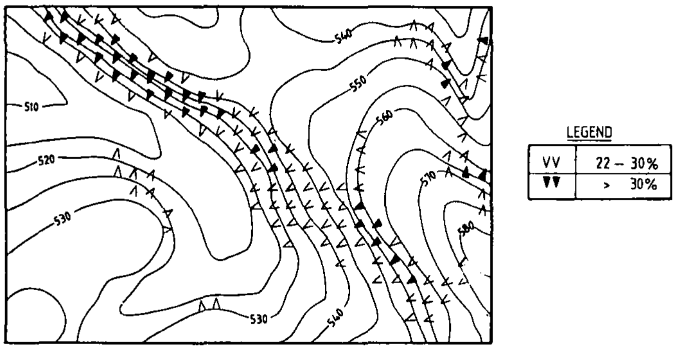

FIGURE 2 Extract from a slope analysis map.

Aspect: the slope aspect can be extracted in a similar way. For example, all north facing slopes with a slope greater than, say, 10% could be demarcated.

Grade: the computer will draw a line at a user-defined gradient from the required starting point on the DTM. This is useful in siting terrace banks and extraction roads (Dinkele, 1991). The ISOGRADE module which does this is being developed specifically for SASEX requirements.

The above can be used in the GIS environment, where other parameters such as soils and climate can be integrated to enable holistic planning for maximum protection of resources.

Engineering and hydrology

Modules are available to interpolate (from the DTM) profiles and cross-sections, calculate bulk earthwork volumes, cut and fill and other applications used in the design of roads and dams. The government Department of Agricultural Engineering uses these modules for the design of farm dams and conservation structures (*Smith, personal communication). For calculations of this type, the DTM has to be accurate and would therefore be preceded by a detailed field survey with a high density of positional data. Water reticulation and irrigation packages also make use of surface modelling in calculating water pressure, head, flow and velocity. Hydrologists worldwide are making increasing use of GIS to integrate geographic or spatial data with simulation models. Surface modelling can provide an important input here with regard to both catchment morphology and climatic data, sparing manual encoding of parameters (Tim *et al.*, 1992).

Meteorology

The Computing Centre for Water Research (CCWR) in Pietermaritzburg has rainfall data sets available, which cover the entire country (Gorven and Dent, 1988). These data were developed by the Department of Agricultural Engineering at the University of Natal (which is now working on similar data for evaporation and temperature). The rainfall data can be transferred from the mainframe computer at the CCWR and used to develop a DTM in which the surface model is of rainfall distribution. The DTM can then be analysed either on its own or can be brought into the GIS as a 'backdrop' to a map of a farm or region. The estimated annual rainfall statistic at any geographical position can then easily be queried. This is a most effective way of storing and analysing climatic data for quick and reliable estimates of annual means, as it circumvents the need to locate records from the nearest weather stations and provides a continuous coverage of statistically derived data.

Soils

DTMs have been used to assist in chemical and physical analysis of soils. In this instance the x, y co-ordinate would be the geographic position of the soil sample and the z value would usually be some chemical concentration, physical property or pH at that point. Isolines for these properties can then be generated and displayed at the required contour interval. Soil depth can also be modelled in this way.

In the United States soil sampling machines have been equipped with a Global Positioning System (GPS), which is a satellite based radio navigation system for determining position (Harrison *et al.*, 1992). For each sampling position, latitude, longitude and elevation are accurately calculated and stored electronically with the sample number, for later assimilation into a GIS. This frees the operator from having to sample at specific points on a measured grid, and enables him to move at will or as dictated by topography, vegetation or other physical factors.

Pest and disease

Any pest and disease data where a pest concentration or disease level is allied to a geographic position could be modelled as a surface. For the DTM to be accurate, the sample points would have to be at a reasonably even density on the ground, whether this be at a field, farm or regional scale.

Conclusion

Surface modelling is already an established tool in the fields of land use planning, engineering, hydrology and meteorology. When used in the GIS environment it becomes more than a planning tool, because the real strength of a GIS is not simply its ability to work with spatially referenced data, but also the way in which it permits different data sets to be integrated.

Technological advances in personal computing have made surface modelling far more accessible to the average user, and it is no longer found only in the enclaves of large research organisations. For this reason it is bound to become more commonly used both in structural planning and by many disciplines in data analysis exercises.

* M Smith, Department of Agricultural Engineering, Cedara

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