

LANDFORM AND EARTH SURFACE

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Summary

The shape of the surface of the Earth is fundamentally important to humans. Terrain form may directly affect a great many things such as: the direction of the flow of water; the clarity of the signal received using a mobile telephone; the perceived degree of attractiveness of the scenery in any one place. Measurement of the shape of the surface of the Earth (that is, landform) is a concern in many disciplines and today a vast range of techniques exist for (i) measuring the height at any location above some datum and (ii) producing a model of the terrain for some area. This Article discusses the relevance, measurement and modelling of landform.

1. Introduction

This chapter will review the principal approaches to sampling topography and modelling terrain digitally. Firstly, some basic details of the kinds of processes that shape the Earth's surface are detailed. Next, the ways in which topography may be modelled are outlined. The focus then moves to the measurement of topography and the generation of models of topographic form. Finally, some issues relating to the quality of DEMs and their application are reviewed briefly.

1.1. Earth Surface Processes and Landforms

Geomorphology is the study of the physical features of the Earth. It is also concerned

with the relationship between these physical features and the underlying geology. There are many detailed introductions to geomorphology and an overview of some very basic concepts is given here.

The form of the surface of the Earth is the outcome of the effect of surface (or exogenic) processes and internal (endogenic, sometimes termed exogenetic) processes. Exogenic processes primarily involve denudation through removal of material by water, ice and wind action. Denudation may be divided into erosion (also termed mechanical denudation; the removal of solid particles) and chemical denudation (removal of dissolved material). Endogenic processes usually result in an increase in elevation and relief. Endogenic processes are divided into three groups: igneous activity, orogenesis and epeirogenesis. Igneous activity is the movement of molten rock (magma) on (or towards) the surface of the Earth. Orogenesis is change in the Earth's crust whereby rock strata are forced up into folds or blocks to form mountain belts. Epeirogenesis is the elevation or depression of the surfaces of continents with little or no folding or fracture. Tectonics is the general term used to describe the various processes (deformation and faulting) which form the features of the Earth's crust. Major morphological features of the Earth include mountain ranges such as the Alps and the Himalayas running across Europe and Asia, and the Andes and the North American Cordillera running along the western edge of the Americas.

1.2. Digital Representation of Terrain Form

Terrain form is represented in a variety of ways. On paper maps, contour lines are commonly used to represent the shape of the terrain in a particular area. In computers, terrain form is usually represented using altitude matrices or Triangulated Irregular Networks (TINs). Tools for creating and handling altitude matrices and TINs are a standard part of Geographical Information System (GIS) software. The altitude matrix and TINs will be described in turn below.

There is a range of terms used to refer to ways of representing topographic form digitally. Different authors use these terms to mean different things. The term Digital Elevation Model (DEM) refers here to any representation of topographic form digitally. The DEM may be considered as a subset of the Digital Terrain Model (DTM). DTMs may represent the spatial distribution of attributes of the terrain in addition to elevation alone. That is, a DTM may include "above-surface" features such as vegetation and buildings, whereas a DEM includes information only on the ground surface. Some authors use the term Digital Surface Model (DSM) in place of the term DTM.

Terrain form may be represented digitally in two key ways: the raster data model and the vector data model. With the raster model, a surface is represented as a grid of cells (also called pixels). The value assigned to each cell represents the attribute of that cell. For example, a cell value of 2.16 may represent an elevation of 2.16 m above some fixed datum. The raster-based representation of topographic form is called an altitude matrix. The altitude matrix is depicted using a range of values with a continuous colour or grey scale (ranging, for example, from white through to grey and black) used to represent the possible values. The vector model represents objects using points, lines and areas (termed polygons). So, spot heights and contour lines are vector-based

representations of topographic features. The TIN is a means of representing topographic surfaces using vectors. Both the altitude matrix and TIN are defined below. A more in-depth account of the raster and vector models is provided (see *Spatial Data Handling and GIS*).

1.2.1. The Altitude Matrix

The altitude matrix (Figure 1) may be defined as a regular grid of numbers which represent elevation above an arbitrary datum (such as mean sea level). The altitude matrix is the most common form of digital terrain data structure. Altitude matrices may be derived directly through remote sensing or through interpolation from a grid of data points that are regularly or irregularly spaced.

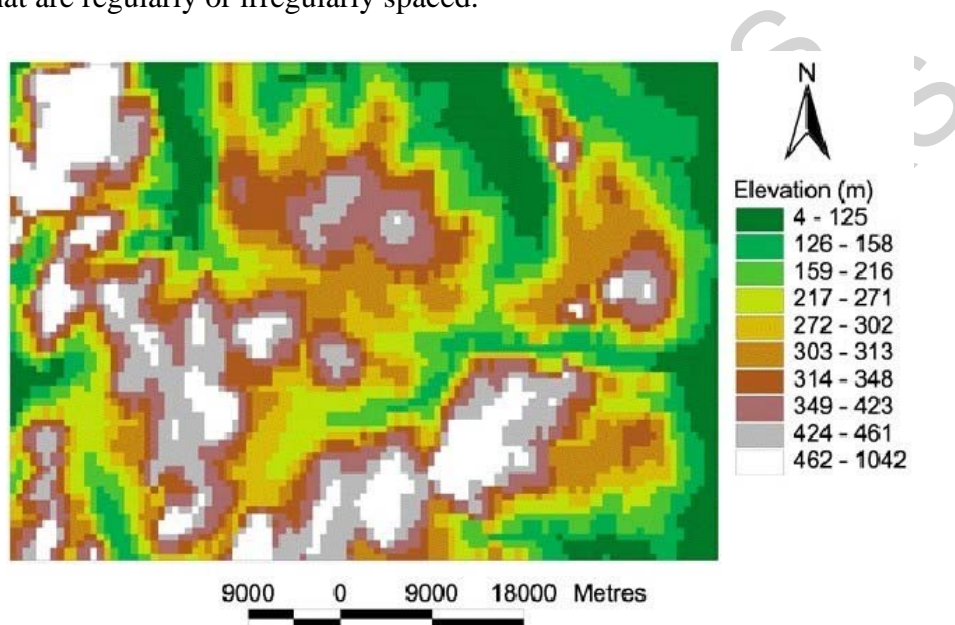


Figure 1: An altitude matrix. The region centres on an area of North Wales.

Altitude matrices have several advantages including the ease with which they may be manipulated. A notable disadvantage is that the regular grid suffers from data redundancy in that homogeneous areas may have many identical (or very similar) values. Conversely, areas with much local spatial variation (for example, mountainous regions) may be under-sampled. Where data storage space is limited it is possible to interpolate maps from a sample using known parameters when the maps are required, rather than storing the map as a whole. A vector-based alternative to raster altitude matrices is provided by the TIN.

1.2.2. The Triangulated Irregular Network

A vector form of digital surface is the TIN. The TIN models a surface as a series of contiguous, non-overlapping triangles. Each TIN is composed of triangle nodes (positional measurements) connected by lines. The lines enclose triangular faces. An elevation value is then interpolated for every position on the TIN. In Figure 2(a) a TIN is illustrated while in Figure 2(b) the faces of the triangles are assigned colours

according to the elevation interpolated. TINs may be generated using Delauney triangulation which ensures that a circle drawn around the three nodes forming a triangle does not contain any other nodes.

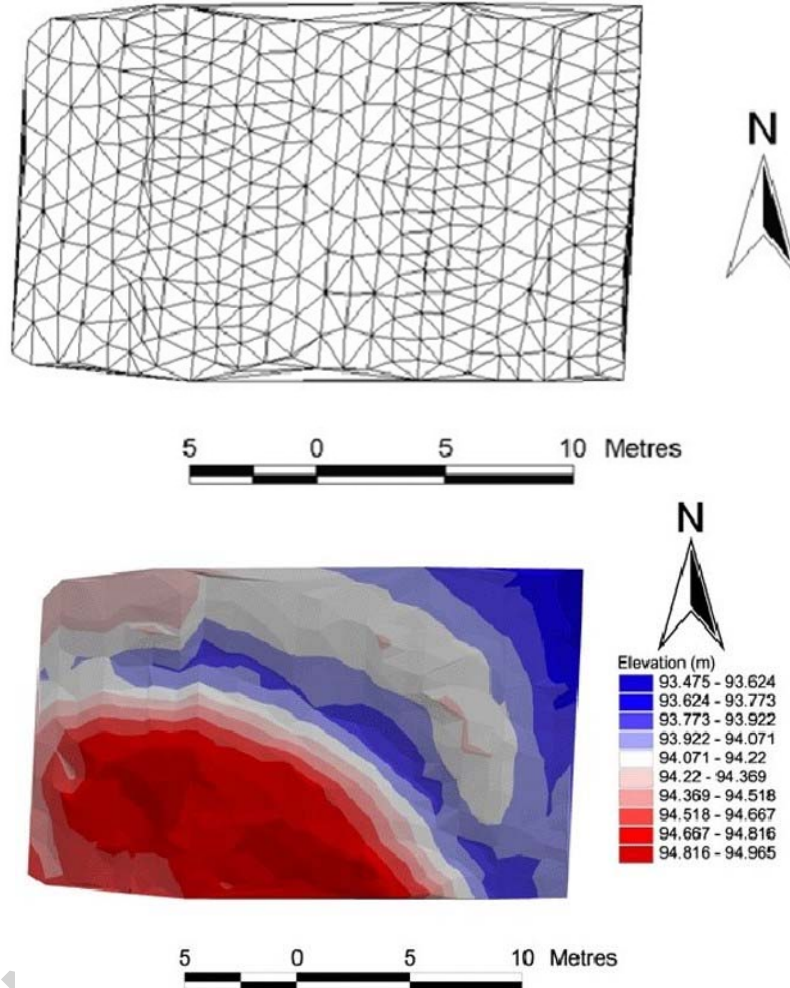


Figure 2: (a) A Triangulated Irregular Network (TIN). The nodes which form the triangles are measured elevations. (b) Shaded TIN, where the colours represent elevations.

A key advantage of TINs over altitude matrices is the capacity to vary the number of data according to the complexity of the topography. That is, it is possible to have more observations in a mountainous area than across a river floodplain. So, for a TIN to represent topographic form accurately, it is required that only significant features in the landscape, such as breaks in slope, are recorded. In contrast, an altitude matrix has an even spacing of cells for all areas irrespective of the amount of variation in the topography.

2. Sampling Landform

DEMs are now available at a range of scales from the micro-scale for analyses in limited regions to the macro-scale, applicable for continental and global analyses. If

measurements are required at sub-centimetre accuracy then field survey by the user is the most likely solution. However, if only sub-metre accuracy is required then appropriate DEMs derived using a range of remote sensing technologies are available.

The following sections are concerned with the sampling of terrain data. There is a wide range of technologies available for sampling terrain data and detailed reviews are available. Section 3 focuses on ground-based survey while section 4 discusses remote sensing of landform. In section 6, which focuses on data quality, the need to balance the spatial variation in elevation in a particular region with the sampling strategy (that is, grid spacing) is stressed. For example, the sampling grid in a mountainous area will need to be finer than the sampling grid in an area with smoother topography to enable construction of DEMs with the same precision in both areas. An additional concern is the sample configuration itself. That is, if samples are taken at a regular interval (rather than selectively at locations with major breaks of slope) then a triangular grid has been shown to be more efficient than a square grid, although the latter is usually preferred in practice.

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Biographical Sketch

Chris Lloyd is Lecturer in Geography (Geographical Information Science) in the School of Geography, Queen's University, Belfast. He has research interests in geostatistics, GIS, remote sensing and archaeology.