The NCGIA GIS Core Curriculum for Technical Programs

UNIT 6: TERRAIN DATA

Written by Barry Bitters, Imaging/GIS Specialist, Lockheed Martin Information Systems

---

[Note: outdated links have been removed from the following sections.]

Index

        - Value-Added Vendors
        - Engineering Firms
        - Home-made

- Competency

    - Learning Objectives
    - Vocabulary
    - Topics
    - Unit Concepts

    - Where can Digital Terrain Data be Found?
        - US Navy 10' Data
        - ETOPO5
        - GTOPO30
        - USGS DEM
        - DCW
        - DLG

    - Where can Digital Terrain Data be Downloaded from on the INTERNET??
    - Exercise: Downloading Digital Elevation Data from the INTERNET.

- Mastery

    - Learning Objectives
    - Vocabulary
    - Topics
    - Unit Concepts

    - Planning a Digital Terrain Data Collection Effort
    - What are the Tasks required to locate digital terrain data?
    - What Constitutes Being the Best Data for A Job??
    - How to Get Elevation Data into the Desired Format for a Specific Job??
    - Exercise: Download and Reformat Elevation Data.

- Resources

    - Literature
    - Software
    - Data
    - Tutorials
    - Synthetic Terrain Generation

Context

Elevation data describes the shape of the Earth's surface and is important in the development of many human and Earth resource models. This information is used in conjunction with other data such as population, vegetation, soils, climate or agricultural information to tell a more complete story of the interaction of people and the environment.

The most fundamental type of elevation data is the raw elevation values of a single point on the Earth's surface. This is a measured height of a specific point on the Earth's surface, relative to some reference plane (termed a vertical datum). Many digital elevation values stored in an orderly fashion are often called a Digital Terrain Model (DTM). DTMs provide a convenient method for storing and representing elevation data.

DTMs are increasingly becoming the focus of attention within the larger realm of digital topographic data. This is because the fundamental nature of the data, and the insight that the elevation information can provide. The insight that DTM data can add is becoming extremely valuable in numerous applications within the fields of Earth, environmental and engineering science. This is due, at least in theory, to the fact that DTM can be used to simulate the true elevation, slope and aspect of the Earth's surface.

Research and application of global change science, for example, is an area where the need for quality topographic data is essential to creating Earth based intellectual models of real world situations. Simulation and virtual reality applications are other areas of study that also require terrain elevation data.

Example Application

A GIS/image processing firm has been subcontracted to create a flight simulator database. Many airlines and most of the world's air forces provide simulator flight training capabilities for aircrew members. These flight simulator systems, although very expensive have been shown to be an economical alternative to the expenses that are encurred from actual aircraft flight time. An integral part of each aircraft flight simulator is a geographic information system (GIS)/image database. This database is designed to allow the generation of realistic out-the-cockpit views of the world in real-time.

Generally, flight simulator visual databases are composed of four separate elements:

- **A Geographic Information System - GIS (the Feature Database).**
- **A Ground Imagery Database (the Global Texture Database).**
- **A Library of 3-dimensional Feature Models (the Feature Model Library).**
- **A Digital Terrain Model - DTM (the Terrain Database).**

These database elements when digitally merged together in real-time can be used to create a series of terrain visualizations. The trick in flight simulator database generation is to display sixty scenes per second. At the sixty scene per second display rate, the human mind perceives continuous motion instead of each individual scene.

To be successful at simulator database generation, each element is created independently using processes that insure positional correlation between all other simulator database elements. For example, feature information is stored in a separate

process from those processes used to collection elevation data. However, it is essential that feature positions be compared to elevation data to insure that elevation data does not contradict the presents of features. For example, stream data must always be checked to insure that elevation data does in fact portray a proper downhill flow. Elevation data for areas of open water must be checked to insure that shorelines and water surfaces are at continuous elevations.

The simulator database for which we are collecting data, is for the area around the Logan International Airport in Boston, Massachusetts. In the exercises during this unit of instruction, we will to locate elevation data for this region. Generally, three levels of elevation detail are required: a low-resolution source, a medium-resoultion source, and a high-resolution source. These levels of resolution generally coincide with the ranges of map scale: high-resolution - large scale, medium-resolution - medium scale, and low-resolution - small scale. During the exercises, we will identify various elevation data sets for the Boston area, download some of this data from the Internet, and display and reformat some of this newly obtained elevation data. The combined learning experience of all the exercises will be similar to planning and data acquisition phases of a real world project.

Learning Outcomes

The following list describes the expected skills which students should master for each level of training.

Awareness:

> To attain an awareness level of this section the student must achieve a general understanding of the uses of digital terrain data, knowledge of available types of elevation data and where to obtain them.

Competency:

> To reach a competency level of this section the student must know where to obtain various types of elevation data. The student will know how to download various types of elevation data.

Mastery:

> To attain a mastery level of the material in this section the student will have had experience at independently planning and executing an elevation source data collection operation.

Preparatory Units

Recommended:

UNIT 38 - Digital Elevation Models

UNIT 39 - The TIN Model

Complementary: NONE

Awareness

To attain an awareness level of this unit the student must achieve a general understanding of the uses of digital terrain data, knowledge of available types of elevation data and where to obtain them.

Learning Objective:

1. Student can define basic vocabulary relating to digital elevation data sets.
2. Student can explain the broad uses of digital elevation data.
3. Student can explain digital elevation data types.
4. Student can define the sources of digital terrain data.
5. Student will identify the global, digital, elevation data sets.
6. Student will identify some regional digital elevation data sets of the United States.

Vocabulary

- DEM
- DTED
- DTM
- ETOPO5
- GTOPO30
- NIMA
- NOAA
- TIN
- USGS

Topics

Unit Concepts

1. What Are Digital Terrain Data Sets Used For??

DTMs are used in many applications in earth science, environmental studies, and engineering. Their earliest use dates back to the 1950s when the U.S. Air Force first experimented with aircraft simulator technology. Since that time, DTMs have proved to be an important ingredient for all types of geographic modeling and the analysis of spatial topographic information. Broadly, there are five main application fields where DTMs are used:

- Civil Engineering
- Earth Science Applications
- Planning & Resource Management

- Surveying & Photogrammetry
- Military Applications

Civil engineering: Civil engineers are mainly interested in using DTMs for cut-and-fill computations involved with road design, site planning, and volumetric calculations in building dams, reservoirs and the like. It may be pertinent to point out that owing to such overt concerns with volume and design, calling a DTM a "terrain model" has more relevance to a civil engineer than other DTM users.

Earth sciences: The Earth science applications center mainly around specific functions for modeling, analysis and interpretation of the unique terrain morphology. These may include drainage basin network development and delineation, hydrological run-off modeling, geomorphological simulation and classification, and geological mapping. Generating slope and aspect maps, and slope profilesfor creating shaded relief maps is a popular usage that employs DTMs.

Planning and resource management: This application of terrain data is composed of diverse fields including remote sensing, agriculture, soil science, meteorology, climatology, environmental and urban planning, and forestry, whose central focus is the management of natural resources. Examples include site location, DTM production from remote sensing, the geometric and radiometric correction of remote sensing images, soil erosion potential models, crop suitability studies, wind flow and pollution dispersion models.

Surveying and Photogrammetry: One of the main objectives of employing surveying and photogrammetry is in building reliable DTMs, evaluating their accuracy towards finally producing high quality elevation data. This may be done in a number of production-related ways: field survey, or photogrammetric data capture and subsequent editing, orthophoto production, data quality assessment, or extraction from topographic maps.

Military applications: The military is not only a leading consumer of DTMs, they also are a significant producer. Most military operations depend on a reliable and accurate understanding of the natural and manmade terrain. This includes a detailed modeling of elevation, slope, and aspect of the land surface. The military's use of DTMs employs a combination of the methods used by all the previous applications. Examples would include simple visualization, intervisibility analysis of the battlefield, 3-dimensional display for weapons guidance systems and flight simulation, and radar line-of-sight analyses.

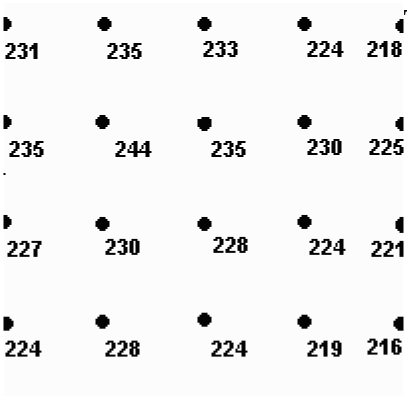
2. What are the standard formats for terrain data??

The basic design of a DTM is based on the structure used to represent it. DTMs can be represented by a line, or point method, or mathematically. Efficient means for mathematically describing large areas of the Earth's surface have not been found. The level of detail essential in modern earth resource monitoring systems can not be approached using the current mathematical processes available to describe irregular surfaces. A variety of data structures have been tried and tested for storing and displaying topographic surfaces, however only three have become the most popular and best explored:

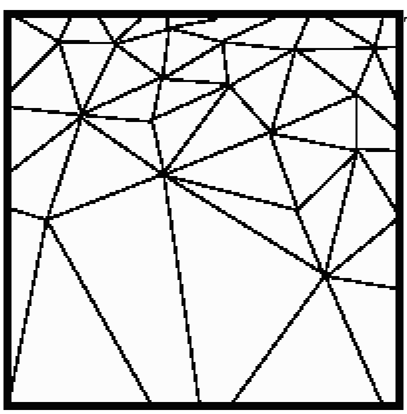
1. The rectangular grid or Digital Elevation Matrix (DEM)

2. The triangular irregular network (TIN)
3. The contour line structure Digital Contour Line

All three methods employ representations that use a point or line model for the storage of elevation data. Two other formats will occasionally be encountered: DXF format and ASCII. These are essentially variations on free text listings of values for point geographic positions.



The digital elevation matrix or rectangular grid of evenly spaced elevation values is the most commonly used digital modeling structure for a DTM. This is because the data structure of a grid shares much similarity with the file structure of digital computers. Both store elevations as a two-dimensional array (every point can be assigned to a row and a column). Because of this similarity of storage structures, the topological relations between the data points are recorded implicitly. No hard encoding of each geographic position is necessary. This streamlines both information processing and algorithm development.



The triangular irregular network (TIN) model provides a network of connected triangles with irregularly spaced nodes or observation points with stored coordinates describing the point location in x, y, and z. Its major advantage over an elevation matrix is its ability to store more information in areas of complex relief, and avoid the problem of gathering a lot of redundant data from areas of simple relief. However, the disadvantage of this digital data model is that algorithm development is more difficult because of the random positioning of valid data points and a requirement for complex interpolation.

The last data structure for storing digital elevation data is the contour line structure. This system is based on storing a vector version of the traditional printed contour line. This model is convenient because minimal hardware and software is required to transform hard-copy map contour lines into digital contour lines. However, algorithm development is very difficult and of the three models this one requires the most storage space.

3. Where can digital terrain data be found??

Derived from medium- and small-scale mapping source materials, a significant archive of elevation data is available for the entire world. Availability of higher resolution elevation data varies based on the area of interest. The primary sources of digital terrain data are:

- National Oceanic and Atmospheric Administration (NOAA)
- United States Geological Survey (USGS)
- National Imagery and Mapping Agency (NIMA) formerly the Defense Mapping Agency (DMA)
- Foreign Mapping Organizations
- Value-Added Vendors & Engineering Firms
- Home-made Elevation Data

National Oceanic and Atmospheric Administration (NOAA)

U.S. Navy 10-Minute Elevation Data

The U.S. Navy 10-Minute Elevation Data is a global, digital elevation data set at a resolution of 10 arc minutes. Each elevation sample is approximately 10 nautical miles apart. It was originally prepared by the Navy Fleet Numerical Oceanography Center (FNOC) at Monterey, CA. For each 10x10 arc minute area the set includes elevation, minimum elevation, maximum elevation, orientation of ridges, terrain characteristics, and urban development information. The FNOC began creating the original 10' terrain data set in the mid-1960s; work extended into the early 1970s. The main sources for the data were the US Department of Defense Operational Navigational Charts (ONC), scale 1:1,000,000. For certain regions the ONCs were not available; for such areas, selected charts from the Jet Navigation Charts and World Aeronautical Charts were used. The charts were hand-read out to paper forms, and then read by optical character reader to magnetic tape. The values were estimates from contour lines. Isometric graphs were made for quality control, such as checking terrain features. Later, other errors were corrected by the National Center for Atmospheric Research in Boulder, Colorado.

Example of the uses of the U.S. Navy 10 Minute Data

ETOPO5

ETOPO5 was generated from a digital data base of land and seafloor elevations on a 5-minute latitude/longitude grid. The resolution of the gridded data varies from true 5-minute for the ocean floors, the U.S.A., Europe, Japan, and Australia to 1 degree in data-deficient parts of Asia, South America, northern Canada, and Africa. Source data used in the production of the ETOPO5 data are as follows:

- Ocean Areas - U.S. Naval Oceanographic Office;
- U.S.A., W. Europe, Japan/Korea - U.S. Defense Mapping Agency
- Australia - Bureau of Mineral Resources, Australia;
- New Zealand - Department of Industrial and Scientific Research, New Zealand
- Remander of the world land masses - U.S. Navy Fleet Numerical Oceanographic Center (FNOC)

Example of the uses of the ETOPO5 data

U.S. Geological Survey (USGS)

Global 30 Arc-Second (GTOPO30) Elevation Data

The Global 30 Arc-Second (GTOPO30) elevation database was created by the USGS Topographic Data group at the EROS Data Center. This elevation data set provides worldwide coverage at a 30 arc second post spacing (approximately 700 to 1000 meters). This database is a composite of many data sources. The primary data source is the U.S. National Imagery and Mapping Agency's Digital Terrain Elevation Data (DTED) Level 1. The Global 30 Arc-Second elevation database consists of the generalized DTED data where ever it is available. Gaps in the generalized DTED data are filled with the best available data from other sources. One of the sources for filling gaps is elevation grids generated from the contour data provide from the Digital Chart of the World. If neither DTED or DCW data are available, then either ETOPO5 or elevation contours digitized from topographic maps were used.

Image of Entire World With GTOPO30 Color Elevation Tint

Graphic Showing Sources of GTOPO30

Graphic Showing GTOPO30 Distribution Tiles

Digital Chart of the World (DCW)

The Digital Chart of the World (DCW) is a worldwide vector based geographic information database. This data set, distributed on CD-ROM has a hypsography (contour) information layer that contains small-scale elevation information. With the proper software this data can be converted into point elevation data. The DCW was digitized from 1:1,000,000- and

1:2,000,000-scale base maps with 1,000 foot contour intervals and supplemental 250 foot intervals below 1,000 feet. In areas of high relief, the contours from the DCW readily supports a resolution better than 30 arc second elevation data. However, for areas of low relief, the 30 arc second elevation clearly shows more topographical structure. In other words, in relatively flat areas of the world, this information will probably not improve on the detail of the elevation information stored in the ETOPO30 data set. However, in areas of medium or high relief, the elevation data that can be generated from the DCW data set can be used when resolutions better than 30 arc seconds are required, especially when detailed linear hydrographic information is used to produce the final digital elevation data. Some private concerns are creating substitutes elevation data from DCW for missing 3 arc second elevation data.

Example of DCW Elevation Data Use.

Digital Elevation Model (DEM)

The Digtial Elevation Model (DEM) elevation data, produced for the United States and its possessions by U.S. Geological Survey comes with sample spacing varying from 30 meters for 7.5-minute DEMs to 3 arc seconds (70-90 meters) for 1:250,000 scale maps. All DEM data are similar in logical data structure and are ordered from south to north in profiles that are ordered from west to east.

7.5-minute DEM data are produced in 7.5-minute units which correspond to USGS 7.5-minute topographic quadrangle map series. 7.5-minute DEM data consist of a regular array of elevations referenced horizontally on the Universal Transverse Mercator (UTM) coordinate system of the North American Datum of 1927 (NAD 27).These data are stored as profiles with 30-meter spacing along and between each profile.

15-minute DEM data correspond to USGS 15-minute topographic quadrangle map series in Alaska. The unit sizes in Alaska vary depending on the latitudinal location of the unit. 15-minute DEM data consist of a regular array of elevation referenced horizontally to the geographic (latitude/longitude) coordinate system of North American Datum 1927 (NAD 27). The spacing between elevations along profiles is 2 arc seconds of latitude by 3 arc seconds of longitude.

30-minute DEM data covers a 30-minute by 30-minute area which correspond to the east half or west half of the USGS 30- by 60-minute topographic quadrangle map series for the conterminous United States and Hawaii. Each 30-minute unit is produced and distributed as four 15- by 15-minute cells. 30-minute DEM data have the same characteristics as the 15-minute DEM data except that the spacing of elevations along and between each profile is 2 arc seconds.

1-degree DEM data are produced by the Defense Mapping Agency in 1-degree by 1-degree units which correspond to the east half or west half of USGS 1- by 2- degree topographic quadrangle maps series, for all the United States and its territories. 1-degree DEM data consist of a regular array of elevations referenced horizontally using the geographic (latitude/longitude) coordinate system of the World Geodetic System 1972 Datum. A few units are also available using the World Geodetic System 1984 Datum. Spacing of the elevations along and between each profile is 3 arc seconds with 1,201 elevations per profile. The only exception is DEM data in Alaska, where the spacing and number of elevations per profile varies depending on the latitudinal location of the DEM.

Examples of 1:250,000 DEM Data

DEM Data User's Guide Download Site

Condensed DEM Data User's Guide with Examples

Digital Line Graph (DLG) Contour Layer

A standard form of digital cartographic data published and distributed by the US Geological Survey is the Digital Line Graph (DLG). This product line contains detailed hypsographic and hydrographic information that can be used to produce accurate digital elevation matrices. Three distinct types of DLG data are available for the US and its territories:

1. Small-scale DLG digitized from the 1:2,000,000 sectional maps of the National Atlas of the United States and its possessions.

2. Medium-scale DLG are digitized from 1:250,000 USGS topographic quadrangle maps of the U.S. and its possessions.

3. Large-scale DLG are digitized primarily from 1:50,000 to 1:24,000 scale USGS topographic quadrangle maps of the U.S. and its possessions.

Examples of DLG Data

Data User's Guide Download Site

Condensed Data User's Guide

National Imagery and Mapping Agency (NIMA)

The U.S. National Imagery and Mapping Agency (NIMA) is chartered to provide mapping, charting, and geodetic data for areas of the world of potential interest to the U.S. Department of Defense. This charter and also because of national alliances the NIMA area of interest is extensive. Because of these same alliances and other national security related factors, NIMA must restrict the distribution of much of the mapping and imagery data. In fact, for the same reasons, information concerning the availability of data is restricted.

Digital Chart of the World (DCW)

The Digital Chart of the World (DCW) is a world-wide, small-scale geographic database produced by the National Imagery and Mapping Agency (NIMA), formerly the Defense Mapping Agency - DMA. The DCW database contains over 1,700 megabytes of data organized on four CD-ROMs. Each CD-ROM contains over 400 megabytes of data structured in approximately 5,000 to 7,000 directories and 30,000 to 40,000 separate files. Many of the feature tables contain over 200,000 feature records with the largest containing 600,000 records. The primary sources of information for the database are 1:1,000,000 scale Operational Navigation Charts (ONCs) and 1:2,000,000 scale Jet Navigation Charts (JNCs). For this reason care should be taken when using this data. Because the data set was derived from small scale representation of the Earth's surface, the level of detail is very low and absolute accuracy is also very low.

However, for small-scale representations of the Earth's surface DCW feature data has many uses. Among the many uses is the derivation of digital elevation data from the stored hypsographic information. Conversion of the vector contour lines can provide a low to medium resolution digital elevation matrix.

Vector Map (VMap) Level 0

Vector Map (VMap) Level 0 also known as DCW Edition 2, is an updated and reformatted version of the Digital Chart of the World. It was designed to provide low-resolution vector-based geospatial data of the world. During the revision process, some of the deficiencies identified in the original DCW database were corrected. Some additional elevation data was added, however, large portions of the equatorial zonesof the world still lack contour data. Vegetation data was added to North America, however, much of the world still lacks detailed vegetation information.

As with the DCW data, VMap Level 0 can be used as a source of digital elevation data. Conversion of the vector contour lines can provide a low to medium resolution digital elevation matrix.

Digital Terrain Elevation Data (DTED) Level1

Level I DTED is the basic medium resolution elevation data source for all military activities and systems that require landform, slope, elevation, and/or gross terrain roughness in a digital format. Distribution of DTED and the Digital Data Products catalog is authorized to the Department of Defense, U.S. DoD contractors and to U.S. government agencies supporting DoD functions. Other requests shall be referred to Headquarters, NIMA.

DTED Level 1 is a medium resolution source of raw elevation data with elevation sampling at 3 arc seconds (70 to 100 meters apart) It is produced and distributed by the U.S. National Imagery and Mapping Agency (NIMA), formerly the Defense Mapping Agency - DMA. It is currently used in numerous military systems and applications that require digital data on terrain landforms, slope, elevation, and terrain roughness.

Detailed Description of DTED Level 1

DTE DMil Performance Specification Download Site

Digital Terrain Elevation Data (DTED) Level 2

Digital Terrain Elevation Data (DTED) Level 2 is a high resolution source of raw elevation data produced and distributed by the U.S. National Imagery and Mapping Agency (NIMA), formerly the Defense Mapping Agency - DMA. DTED Level 2 is a high resolution digital elevation data set with elevation sampling at 1 arc second (20 to 30 meters apart).

As with DTED Level 1, distribution of DTED Level 2 is restricted to the U.S government, certain military contractors, and selected foreign national government agencies. It is currently used in numerous military systems and applications that require digital data on terrain landforms, slope, elevation, and terrain roughness. Because of the density of this data set and the size of the files necessary to cover large areas, only small scattered patches of DTED Level 2 are currently available.

Foreign National Mapping Agencies

Most nations have organizations similar to the US Geological Survey and/or the National Imagery and Mapping Agency (NIMA), with the express charter of producing mapping and mapping related digital products for there region of the world. These organizations, as is the case with NIMA, are often restricted by alliances and security regulations that will often prevent the distribution of detailed mapping data.

For a detailed catalog of available worldwide elevation data from all sources, consult Bruce Gettings' Digital Elevation Model Catalog. This Web site is designed to send to each requestor five email files. These files, once sequentially reassembled constitute a comprehensive listing of all readily available elevation data worldwide. It does not include information on any data that has limits placed on distribution. It also does not have a detailed listing of hard copy map coverage with printed contour data.

Third-Party Value-Added Data Commercial Data Sources

There are numerous third-party, value-added commercial data sources that, for a price will provide digital elevation data throughout the world. For example, the British firm Woolleysoft advertises a 75 meter DEM data set of Europe from the Atlantic Ocean to the Ural Mountains. Several U.S. firms resample and add information to the standard Digital Chart of the World (DCW) and offer the value-added data for sale.

Engineering/Aerial Photographic Firms

Photogrammetric from aerial/satellite imagery

SPOT, Landsat, or aerial photography when viewed in stereo show exaggerated elevation detail. However, when sound mathematical procedures are applied to digital stereo imagery very accurate elevation data can be extracted. Photogrammetric elevation data capture can be performed from either stereo aerial photography or stereo satellite imagery such as SPOT or Landsat. Additionally, there are a number of newer sources that are also being developed for elevation data extraction. These include radar, laser altimetry, and synthetic aperture radar (SAR) interferometry. Although these forms of imagery may not come under the classical photogrammetric discipline, the mathematical approach to elevation extraction is derived directly from classical photogrammetry.

The ability to exploit detailed and accurate elevation information from stereo photography is not a new process. Sound mathematical procedures have been in existance for many years. It is a relatively recent development though, that allows this type of processing to be performed on inexpensive workstations.

However, beware of certain pitfalls in purchasing and developing a photogrammetric capability in your organization. Initial startup costs, though relatively inexpensive are usually in excess of $150,000 per workstation. This does not include the expense of operator training, which is $10,000 or more per operator for a formal classroom experience.

Photogrammetric Processing

Examples of Photogrammetric Products

Field Survey

Elevation data derived from field survey operations is the most accurate method of obtaining data. This is done by physically taking measurements along a grid of positions on the ground. The values obtained during the field survey are subsequently stored in a digital form. Very high levels of precision are attained using this method of digital elevation data collection. However, because of the amount of time required to obtain this level of detail, this is the most expensive and most time consuming method of producing digital elevation data. Because of the time required, it is only feasible to use such ground surveys for very small projects. Traditionally, these project are small housing or commercial developments.

This data is usually in hard-copy, elevation contour format, however, more and more civil engineering organizations are creating and storing XYZ ASCII text data. This information is usually not available for download but must be obtained directly from survey and civil engineering firms which have worked in the region of interest.

Cartographic

Since the mid-1980s scanning technology has been used extensively in the digital data capture arena. Many practitioners had the vision that scanning technology, along with a black-box approach to raster-to-vector conversion, would be the solution to their digital data capture problems. This black-box concept was based on the idea that using advanced neural-net and other specialty artificial intelligence software, hard-copy documents could be converted into a GIS database with little or no human intervention. Over fifteen years have passed and still no black box exists that will perform raster-to-vector conversion in such a way that minimal editing is necessary. Large amounts of capital have been invested in research into automated data conversion systems. For a variety of reasons, such as vaying source material quality, legibility, and reliability, the black box approach to automated data conversion is still not possible. However, a rational mixture of automated and manual processing can be used to efficiently convert linework on hard-and soft-copy maps into a DTM. There are currently two accepted processes for capturing contour line work: (1) manual digitizing or (2) scanning and vectorizing.

A broad outline of the primary steps involved in the cartographic generation of digital elevation data follows:

1. Plan Digital Elevation Data Creation.
2. Create Vector Elevation Data.
    - Create digital contour information. This can be through table-top or heads-up digitizing.
    - Scan hard-copy contour information and perform a raster-to-vector conversion.
3. Geo-Reference to Datum Plane.
4. Perform Quality Control Checks of Vector Data.
5. Convert to Triangular-Irregular Network (TIN).
6. Perform Quality Control Checks of TIN data.
7. Convert from TIN to evenly sampled matrix of digital elevation values.
8. Perform Quality Control Checks of Raster Elevation Data.

DTMs derived from digital hypsography or contours on hard-copy maps are perhaps the most common of all sources. This is because digital hypsographic data have been developed from analog maps for the longest time when compared with the other sources. Contours from analog maps are normally digitized by manual digitizing, semi-automated line-following, or automatic raster-scanning. After the linework has been captured in a digital form, the data are geo-referenced to the datum plane, vectorized, edited and attributed with elevation values.

The DCW hypsography (contour) information layer is included on all four DCW CD-ROMs. The DCW was digitized from 1:1,000,000 and 1:2,000,000-scale base maps with 1,000 foot contour intervals and supplemental 250 foot intervals for areas below a 1,000 foot elevation. In areas of high relief, the contours from the DCW readily support a resolution better than the 30 arc second elevation data. ARC/INFO algorithms current exist that will create medium resolution DEM data from the DCW hypsography and and linear hydrography layers.

If USGS Digital Line Graph (DLG) materials at 1:100,000 scale or better are available, software that will allow the conversion of this data into a digital matrix of elevation values can be used to create very detailed digital elevation data.

Generated locally

Early elevation data was generated locally using manual interpolation methods. This involved manually interpolating each digital elevation value from contour line information on hard copy maps. Use of this time consuming process is limited by the time required to create an adequate data set and also by the lack of accuracy (especially when considering the operator fatigue factor.) For obvious reasons, this process is rarely used for generating digital elevation data.

There are currently two processes that can be used to generate elevation data locally:

- Cartographic
- Photogrammetric

The cartographic process, described above, involves either manually digiting contour lines or scanning and performing a raster-to-vector conversion. A TIN is then created from the resulting data, and a DEM is generated as final output.

The more expensive photogrammetric process, also described above, is only available within the UNIX workstation environment. However, it will soon be available on the Windows NT platform. This software will then be available to a wider portion of the topographic community.

Table 1. Existing Digital Terrain Model Data.

Elevation Data Set	Format	Post Spacing	Linear Distance	Area of Coverage
US Navy 10'	DTM	10 arc minutes	18.4 Kilometers	Global
ETOPO5	DTM	5 arc minutes	9.2 Kilometers	Global
GTOPO30	DTM	30 arc seconds	921 meters	Global
DTED Level 1	DTM	3 arc seconds	"100 meters"	Worldwide w/Gaps
DTED Level 2	DTM	1 arc second	"30 meters"	Locally
DLG	Contours	-----	-----	US & Possessions

Table 2. Source Material that can be used to create Digital Terrain Model Data.

Source Material	Format	Elevation Resolution	Area of Coverage
ADRG	Digital Raster	Medium-High	Worldwide w/Gaps
DCW	Digital Vector	Low	Worldwide w/Gaps
Paper Maps	Hard Copy	Medium-High	Worldwide w/Gaps
Stereo Photos	Hard/Soft-copy	Medium-High	Local
Airborne Radar	Digital RF	Medium-High	Local
Field Survey	-----	High	Local

Exercise - Download the Digital Elevation Model Catalog

1. Go to the Digital Elevation Model Catalog download site:

   [outdated link removed]

2. Perform the steps identified at this site.

3. After all five files have been downloaded, view the data in a text editor or word processor. The files that have been downloaded are a comprehensive listing of all available elevation data worldwide.

Competency

Learning Objectives:

1. The student will know where to find and how to download a variety of elevation freeware and shareware, and data visualizing software from the Internet.

2. The student will know where to find and how to download digital elevation data from the Internet.

Topics

Where, on the Internet is free software to manipulate and display digital elevation??

Often we are prevented from using data because the software tools are not available to manipulate and/or display available data. The data may be in the wrong format, it may need to be edited, or we might just wish to visually inspect a data set prior to installing it into a database. Many times the tools are not readily available to perform these tasks. The result is that data is often overlooked because the software tools to manipulate the data are not available.

However, it is often possible to find free or very reasonably priced software on the Internet, software that will perform the functions necessary. Three categories of downloadable software exist: freeware, shareware, and commercial software.

Freeware, as the name indicates is software that can be downloaded and used at no charge. Freeware is distributed on the Internet as compressed executables and often source code is also included. To uncompressed the software after download requires that decompression software be available in the host computer. Most of these decompression routines are also available for download free of charge on the Internet.

Shareware is software that is also downloadable from the Internet, but use of shareware has restrictions. True shareware is a fully functional version of the software. The owner/author though, has placed a requirement that long-term use of the product is allowed only if the recipient pays a small fee. Short-term use of the product, for testing and demonstration purposes is allowed at no charge. Use and subsequent payment of the shareware fee is on an honors system. It is up to the good will of the recipient to honor the shareware agreement and pay the owner/author when it is required. Some shareware authors encourage prospective purchasers to honor the shareware agreement by disabling critical portions of the software. Quite often saving of data or printing of output is intentionally disabled in the shareware version. Upon paying a shareware registration fee, the disabled portion of the software is made fully functional.

Commercial software is often available for download from the Internet as a demonstration version of the software. Demonstration version of software are severly limited in the functionality that is available to the user. A fully functional version of the software is only available after the software is purchased.

Functional software, either freeware, shareware, or commercial software is readily available throughout the Internet. However, as with any thing that is free, problems may arise when downloading or using the software. Remember that the "health" of all software downloaded from the Internet should be considered suspect until virus checked. Also, there are usually no warranties, express or implied that accompany any software that is downloaded from the Internet. You should always thoroughly test all downloaded software before integrating it into any system.

- **Sol Katz' Freeware Archive** is the best place to find software to manipulate, reformat and view certain types of digital elevation data. An extensive list of free software for conversion to and from Digital Line Graph (DLG), Digital Elevation Model (DEM), AUTOCAD's Digital eXchange Format (.dxf), and XYZ format is available for downloading at no charge. A simple rastor-to-vector conversion program is available. A .dxf viewer is also available for download. The location of this invaluable site is:

  [outdated link removed]

- **Contour Lines to .dxf Format** conversion software is available at the following site:

  [outdated link removed]

- **Landscape Explorer** is a shareware Windows-based 3D landscape modeling program that can generate realistic images of landforms using both digital images and digital elevation data, including USGS DEM. This software is available for download from the following site:

  [outdated link removed]

- **Wilbur** is a freeware terrain visualization software. Wilbur can be downloaded from the following site:

  [outdated link removed]

- **DEM3D** is a Windows 95 freeware for viewing U.S. Geological Survey's Digital Elevation Models (DEM). This is an experimental version of a public domain terrain visualization routine currently under development. Sample DEM data and a user's manual are included. DEM3D can be downloaded from the following site:

  [outdated link removed]

- **3DEM** is a shareware, elevation data, visualization tool that will produce ray traced landscape scenes and flyby animations. It uses USGS Digital Elevation Model (DEM) files, USGS Global 30 Arc Second Elevation Data Set (GTOPO30 DEM) files, NASA Mars Digital Topographic Map (DTM) files, or any topographic data file which is organized by rows and columns of elevation data. 3DEM will also produce realistic fractal landscape scenes. One of three version of 3DEM - Windows 3.1, Windows 95, or Windows NT can be downloaded from the following location:

  [outdated link removed]

- **MicroDEM** is a set of pascal programs with source code which load and display digital elevation data. The software also allows the draping of other digital data to include digital images and maps. The program is shareware and available from:

[outdated link removed]

Where, on the Internet is free digital elevation data??

Downloading information from the Internet can be very easy if you know where to look. Below we've listed some FTP sites for digital elevation data available on the worldwide web. To find out more about each listed site, click on its name and review the contents at the location.

- US Navy 10 Arc Minute Elevation Data

  This data set can be downloaded as a single file at:

  [outdated link removed]

- ETOPO5 - 5 Arc Minute Elevation Data The ETOPO5 World Topographic Dataset is available on the Internet as two downloadable files. These files contain worldwide bathymetric and elevation data in meters with a 5 minute by 5 minute latitude/longitude data density. These files are very large (approximately 8 Megabytes each.) Attempts to download them should only be made during hours of low-use on the Internet.

  ETOPO 5 - Northern Hemisphere

  [outdated link removed]

  ETOPO 5 - Southern Hemisphere

  [outdated link removed]

- GTOPO30 - 30 Arc Second Elevation Data

  The global elevation data available at this site is in the form of 33 very large data files (5-20 megabytes per file). This site has a very convenient map display which allows interactive selection of the region of the world to be downloaded. Because of the size of the files though, downloads form this site should only be performed during low-peak Internet hours. Data for the entire world, when compressed totals 290 megabytes.

  GT OPO30 Download Site

- USGS DEM derived from National Imagery and Mapping Agency (NIMA) sources.

  The only full collection of USGS DEM available on the Internet is the 1:250,000 scale DEM of the US and Hawaii. Other larger scale USGS DEM data sets are available individually at various locations. However, there is no download location, on the

Internet for the entire large-scale DEM data set of the US. This must be obtained through standard procurement channels.

1:250, 000 DEM Data Download Site (by State Name and Map Sheet Name)

1:250,000 DEM Data Download Site (Alphabetical by Sheet Name)

1:25 0,000 DEM Data Download Site (from US Map Graphic)

- DCW Download at Penn State University Map Library

  This site allows interactive download of tiled DCW data for the entire world.

- An alternate site for obtaining DCW of the conterminous US only is:

  http://h2o.er.usgs.gov/nsdi/dcw/dcwindex.html

  This extract of the DCW North America data set is a tiled database as shown by the red outlined on the index graphic. Simply click on the map tile to be retrieved. A data set in ARC/INFO workspace format will be downloaded.

- USGS Digital Line Graph (DLG)

  Elevation data in the form of USGS Digital Line Graph (DLG) digital contour lines is available on the Internet in two scales. The entire United States is covered by 1:100,000 Digital Line Graph data and this information is available on the Internet. Only the Hypsography data is required if downloading data for the sole purpose of elevation extraction. 1:100,000 DLG data can be downloaded from the following sites:

  HREF="http://edcwww.cr.usgs.gov/glis/hyper/guide/1_dgr_demfig/states.html">1:100, 000 DLG Data Download Site (by State Name and Map Name)

  1:100,000 DLG Data Download Site (Alphabetical by Sheet Name)

  1:100,000 DLG Data Download Site (from US Map Graphic)

  Large-scale Digital Line Graph digital contour line information is available at varying scales of 1:62,500, 1:50,000, and 1:24,000 for many areas of the United States. Large-scale DLG data can be downloaded from the following sites:

  1:24,000 Download Site (Alphabetical by Sheet Name)

If the Internet locations referenced above do not contain the elevation data required for your particular task, there is another Internet location that will assist you in finding data. However, most of the referenced data is not available thru Internet download and must be obtained through more traditional procurement processes. This site contains a comprehensive worldwide list of references for the most current location of elevation data, both analog and digital. Bruce Gitting's Catalogue Of Digital Elevation Data contains references to digital data in all forms and also the more traditional forms of elevation. This listing itemize all the known elevation data that is available both on the net and through more traditional procurement sources

Exercise 2: Downloading Digital Elevation Data from the Internet

First, download a freeware elevation data viewer.

1. Go to the DEM3D software download site at:

   [outdated link removed]

2. Download the file *dem3d.zip*.

3. De-compress the file using WINZIP or GZIP386. If these decompression routines are not available, they can be downloaded as freeware from the following ftp site:

   [outdated link removed]

4. Perform setup for the dem3d software

Download a small-scale digital terrain data set

1. Go to the GTOPO30 download site:

   [outdated link removed]

2. Download the file: *W100N40* This will provide coverage of the northeastern United States at 30 arc second spacing.

3. De-compress the file using WINZIP or GZIP386.

4. Display the data in DEM3D.

Download a 1:250,000 Digital Elevation Model (DEM)

1. Download a USGS Digital Elevation Model (DEM) from the U.S. Geological Survey's EROS Data Center (EDC) Global Land Information System (GLIS) from the following location:

   [outdated link removed]

2. De-compress the file using WINZIP or GZIP.

3. Display the data in DEM3D.

Download a Digital Line Graph Hypsography Data Set.

1. Download a 1:100,000 scale USGS Digital Line Graph (DLG) in the Optional Format (.LGO) from the following Internet site:

   [outdated link removed]

2. De-compress the file using WINZIP or GZIP.

3. To obtain a DLG viewing capability, download the 45,162 Mbyte file *dlgview.zip* located in the following Internet site:

   [outdated link removed]

4. De-compress *dlgview.zip* using WINZIP or GZIP386.

5. Display the DLG data using the *dlgview* software.

Mastery

Mastery: To attain a mastery of the material in this unit the student will have developed the ability to independently plan and execute an elevation source data collection operation.

Learning Objectives:

1. Student can define those factors that effect terrain data requirements.

2. Student understands the relationship between production requirement and terrain data use.

3. Student understands the impact of the following factors on production.
   - Hardware
   - Software.
   - Production Time.
   - Data Purchase Costs.

4. Student understands the basics of converting between various elevation data formats.

5. Student is aware of the effect of datum and projection on elevation data requirements.

Topics:

Unit Concepts

Learning Objectives:

1. Student can perform data conversions between various types of elevation data formats.

2. Student can display various types of elevation data formats.

3. Student can merge elevation data with image data to create terrain visualizations.

Topics

What are those factors that regulate an elevation data production effort??

The planning effort necessary for the production/gathering of elevation data is not limited to purely an analysis of where the available data is located and how to get one's hands on it. As with any production planning effort, organizational assets and limitations must be compared to project requirements and a "plan of attack" created. It is important that a plan be developed that considers all organizational limitations that have even the slightest bearing on the project. This approach will insure that fewer surprises will arise during the project. The following list generally outlines those factors that must be considered when planning an elevation data collection effort:

- Determine the terrain data requirement, what elevation data is absolutely essential in the production effort.
- Define overall production requirement and finished product/deliverables. This will indicate the final data resolutions that are necessary for the project.
- Define areas of interest. This generates bounding rectangles of the required elevation data sets.
- Identify available hardware and software assets. This indicates how much on-site work can be performed and also how much additional hardware and software must be purchased.
- Identify any training shortfalls that might effect the project. This factor could increase the amount of time necessary to complete the project, or worse require the job to be out-sourced because too much time or money is required to correct the training deficiency.
- Define time limitations. This definitively tells how much on-site work can be performed.
- Define computer storage space limitations. This also will indicate how much on-site work can be performed. Since a limited amount of on-site hard-disk storage means only a small amount of data can be resident at any point in time, extremely large data sets may have to be outsourced.
- Define cost limitations. This will indicate how much data can be purchased and how much must be obtained by various other means e.g. in-house production, Internet download, and "begging-borrowing-and-stealing".

2. What is the logic necessary to determine the terrain data necessary for a project?

The following flow diagram outlines the steps that are necessary in the decision making process when planning which elevation data to use in a project.

- Low resolution elevation data (less than 3 arc seconds post spacing) is required
  - **Download ETOPO5 or GTOPO30**

- Medium resolution elevation data (3 arc seconds post spacing)is required.
  - A DOD project DTED Level 1 and DTED Level 1 is available,
    - **Use DTED Level 1.**

    - No DTED Level 1 available,
      - **Digitize hard-copy map data.**

  - If NIMA is not accessible,

    - Is area of interest within the 50 US states?
      - **If Yes - Download USGS 1 Degree DEM.**

      - **If Not - Check Bruce Gitting's elevation catalog for other available elevation data or plan to digitize hard-copy map data.**

    - Area of interest is outside the 50 US states.
      - **Plan to digitize hard-copy map data.**

- High-resolution data (better than 3 arc second post spacing) is required.
  - DOD project and 100 meter data is OK.
    - **Use DTED Level I when available.**

    - If DTED is not available
      - **Check Bruce Gitting's elevation catalog for other available elevation data or plan to digitize maps or use photogrammetry**

  - If not a DOD project,
    - **Check Bruce Gitting's elevation catalog for other available elevation data or plan to digitize maps or use photogrammetry**

  - DOD project and 30 meter data is OK
    - **Use DTED Level II when available.**

    - If DTED Level II is not available
      - **Digitize maps or use photogrammetry**

  - If not a DOD project,
    - **Check commercial sector & national government**

    - A lot of time but no photogrammetric capability
    - **Digitize or search for commercial sources**

    - A lot of time and a photogrammetric capability
    - **Scan aerial photos and perform photogrammetric extraction.**

- In the US and 100 meter data is required

    - **Use USGS version of DTED Level 1 - 1 DEM**

- In US and 30 meter data is required
    - USGS 7.5' DLG is available?
        - **Use USGS DLG Hypsography and Hydrography.**
    - If DLG is not available digitize maps or use photogrammetry
        - A lot of time but no photogrammetric capability
            - **Digitize or search for commercial sources**
        - A lot of time and a photogrammetric capability is available
            - **Scan aerial photos and perform photogrammetric extraction.**

3. Ensure that the datum and projection of source materials match or are converted to the project datum and projection.

4. Conversions

Murphy's Law of Data Acquisition says that, inevitably, any data that is readily available will be in a format that is incompatible with its intended use. Therefore, it is essential that a suite of elevation data conversion tools be available. Sol Katz's Data Conversion Tool Kit contains a wide variety of PC software to perform many of the conversions that will over time be necessary. A shareware routine - TerrainMap 3.0 (tmap30), provides the ability to import, export, and convert between TINs, DEMs, ASCII text xyz, and contour in DXF format. The shareware version is fully functional on only a small data set whereas there is no limit to the data set size for a fully licensed copy of tmap.

Exercise: Retrieve and Use Software to Manipulate Elevation Data

Perform elevation data conversion.

1. Download the *tmap30.zip* software from the following FTP site:

    [outdated link removed]

2. De-compress *tmap30.zip* into a new directory using WINZIP or GZIP.
3. Execute *setup.exe*in this directory.
4. Display any available DEM data in TMAP3.0.
5. The help display provides procedures for converting between DEM, XYZ, TIN, and contours.

Merge Elevation and other Geographic Data

1. Download the TruFlite software from the following Internet site:

    [outdated link removed]

2. From the same Internet site, in the "50 States" location, download a set of DEM and Tiger data for the same location.
3. Decompress both the DEM and the tiger data using WINZIP or GZIP.
4. Import the decompressed DEM and the Tiger data into TruFlite and create a virtual scene of elevation data and Tiger data draped over the terrain.
5. Execute a fly-thru over the draped terrain.

RESOURCES

LITERATURE

Defense Mapping Agency. 1992. *Development of the Digital Chart of the World*. U.S. Government Printing Office; Washington, DC.

Defense Mapping Agency. 1992. *Military Standard - Digital Chart of the World (DCW) Database: Mil. Specification MIL-D-89009*. U.S. Government Printing Office; Washington, DC.

Defense Mapping Agency. 1996. *Military Standard - Digital Terrain Elevation Data (DTED): Mil. Specification MIL-PRF-89020*. U.S. Government Printing Office; Washington, DC.

Defense Mapping Agency. 1995. *Military Standard - Vector Smart Map (VMAP) Level 0: Mil. Specification MIL-V-89039*. U.S. Government Printing Office; Washington, DC.

Defense Mapping Agency. 1996. *Interface Standard for Vector Product Format (VPF): Mil. Specification MIL-STD-2407*. U.S. Government Printing Office; Washington, DC.

Defense Mapping Agency. 1997. *Draft Vector Product Format (VPF)Symbology: Mil. Specification MIL-PRF-98045*. U.S. Government Printing Office; Washington, DC.

Defense Mapping Agency. 1997. *Draft Vector Product Format (VPF)Design Manual: Mil. Specification MIL-HDBK-853*. U.S. Government Printing Office; Washington, DC.

Department of the Interior. 1990. *Digital Elevation Models Data User's Guide; National Mapping Program Technical Instruction No. 5*. U. S. Geological Survey, Washington, DC.

Hutchinson, M.F. 1988. Calculation of hydrologically sound digital elevation models. *Proc. Third Inter. Spatial Data Handling*. Columbus, OH.

Hutchinson, M.F. 1989. A new method for griding elevation and stream line data with automatic removal of pits. *Jour. Hydrology*. 106:211-232.

Montgomery, Glenn E. and H. C. Schuch. 1993. *GIS Data Conversion Handbook*. GIS World Books, Fort Collins, Colorado.

Environmental Systems Research Institute. 1991. *GRID User's Guide*. Environmental Systems Research Institute. Redlands, CA.

SOFTWARE

Sol Katz' Geographic Software Archive

This is by far the best location for free software to manipulate geographic data. Both source code and executables are available for routines to perform elevation conversion and a variety of other tasks. The conversion routines include dem to dxf, dem to xyz, and xyz to dxf. In addition a contouring routine, a rastor-to-vector software suite and a very nice .dxf viewing tool are available.

MicroDEM - A Terrain Visualization Tool

The MICRODEM program allows the manipulation of gridded digital elevation models (DEMs), satellite imagery, and vector map data like DLG and TIGER. The files in the directory are all self-extracting MS-DOS files. Suggestions, questions or problems with this program should be directed to *pguth@charleston.nadn.navy.mil*.

Contour - A Contour to .dxf Conversion Routine.

With this freeware, digital vector contour data can be converted to .dxf format.

SPLAT - A Contouring Software Package

This software allows the creation of contour elevation data from randomly located points.

qgrid33.zip - A Contouring Software Package

QGrid33 is a software package that allows random data or gridded data to be generated into a set of contour lines. It also converts loaded bmp, gif, jpg files to dxf terrain data.

The package dxft.zip may in the future be found at the following Internet URL:

[outdated link removed]

GMT - a Public Domain GIS

At this University of Hawaii FTP location, the public domain mapping software "GMT" can be found. Because the full set of files are huge mirror sites have been set up in Europe and the US east coast. Use the site that is geographically closest to you to improve transmission throughput. These other sites are: East Coast US and Oslo, Norway

TMAP30 - A Terrain Mapping, Modeling, and Visualization program.

This package allows the creation, editing and viewing of raw elevation data and the visualization of 3D perspective views.

3DEM - Terrain Visualization Software

3DEM will produce ray traced landscape scenes and flyby animations from USGS Digital Elevation Model (DEM) files, USGS Global 30 Arc Second Elevation Data Set (GTOPO30 DEM) files, NASA Mars Digital Topographic Map (DTM) files, or any topographic data file which is organized by rows and columns of elevation data. 3DEM will also produce realistic fractal landscape scenes. At this site, software is available for Windows 3.x, Windows 95, and Windows NT.

Wilbur - Terrain Visualization Software

Although this software is strangely named, it is a very nice terrain visualization routine.

DEM3D - Terrain Visualization Software

DEM3D is a Windows 95 software for viewing U.S. Geological Survey's Digital Elevation Models (DEM). This is an experimental version of a public domain terrain visualization routine currently under development. Sample DEM data and a user's manual are included.

DATA

National Geospatial Data Clearinghouse (USGS node)

This Web site is the home page for information about USGS data holdings. You can browse through pages describing various USGS data series, and when you find a data set of particular interest, you can click on a symbol and see its complete metadata, including instructions on how to order it. Alternately, keywords and latitude/longitude bounds can be used in a powerful searching mode to scan the entire USGS collection. Data themes included are:

- Digital Elevation Models
- Digital Line Graph series (1:2M, 1:100K, and 1:24K)
- Satellite Images (AVHRR, LANDSAT)
- Water themes
- Geologic themes

US GeoData Indexes

These indexes are the same as the graphic indexes showing the availability of the DEM 7.5' and 15' Units, DEM 1-Degree Units, DLG 7.5' and 15' Units, DLG 30' Units, LULC 30' Units, LULC 1-Degree Units, CD ROM Data, and also about 400 DOQ listings.

U.S. Navy 10-Minute Elevation Data

10 arc-minute (approximately 11 statue mile post spacing) elevation data for the entire world.

ETOPO5

5 arc-minute (approximately 5.5 statue mile post spacing) elevation data for the entire world.

GTOPO30

30 arc-second (approximately 0.6 statute mile post spacing) elevation data for the entire world.

DEM of the USA 1:250,000 scale

3 arc-second (100 meter post spacing) DEM data in 1 degree square segments is available for most of the U.S. Beware, the data is in WGS72 datum.

Digital Chart of the World (DCW)

The DCW is a worldwide vector based data set. The following named site allows interactive download of tiled DCW data for the entire world.

- DCW Download at Penn State University Map Library

Digital Line Graph (DLG) Hypsography

Digital contour line information from USGS 1:24,000 scale 7.5 minute quadrangle topographic maps.

Worldwide 2 Minute Sea Floor Topography Data - ETOPO6_2

Digital terrain model of worldwide ocean sea floor at post spacing of two nautical miles.

DEM of the USA 1:24,000 scale

This ftp download site, *[outdated link removed]* has a good selection of high resolution 7.5' DEM files for the US.

Radar Altimetry of Venus

Matrix data files of radar altimetry of Venus from the Magellan satellite are available at *[outdated link removed]*. Data which can be processed by 3DEM are available here as *.img files which are made up of a 2048 byte header followed by 1024 column by 1024 row matrix of 16 bit signed integers (Little Endian) with a 5000 meter grid spacing. Each *.img file has an associated *.lbl file with information about latitude and longitude and other characteristics of the data. This is large scale data, so don't expect to see small detail in the surface. However, you can produce high altitude flybys of Venus from this data.

DTM files for Martian Landscapes

DTM files for a large portion of the Martian landscape are available for download at *[outdated link removed]*. Here you will see a large group of folders with names beginning with the letters "mg" and "tg". Always choose a "tg" folder to get digital terrain data ("mg" files are photo images.) The following files are good choices:

- tg15S067.img - Valles Marineris area

tg00N067.img - Valles Marineris area
- tg45S010.img - Crater Lohse
- tg45S270.img - Crater Krishtofovich
- tg45N070.img - Crater Tanais

Bathymetric Sounding Data

The Web site, *[outdated link removed]* is a source of bathymetric data from several ocean areas of the world. Use the 3DEM software to load this data.

VRML Topographic Map Generator

This site allows the interactive generation of VRML scenes of topographic maps of the world. ETOPO5 data, 5 arc second elevation data is used as the topographic and bathymetric surface. This surface can then be colored based on the actual elevation, or texture mapped with biophere data, AVHRR imagery, or the CIA's World Data Bank texture.

TUTORIALS

Woolleysoft Ltd. - A British Topographic Firm

Descriptions and examples of terrain draping operations.

Digital Elevation Models for Professionals

More examples by Woolleysoft Ltd. of maps and images draped over terrain. There are also two fly-thru demonstrations available for download.

NCGIA GIS Core Curriculum Units 38 &39 - Digital Elevation Models and The TIN Model

These lessons provide an overview of digital elevation models and TINs. Although the entire cuuriculum is currently being revamped, the information contained in these units is accurate and might be helpful as introductory information.

Create A TIN Tutorial

This tutorial demonstrates the proper way to create a TIN in the UNIX ARC/INFO environment. Numerous fragments of .AML code and command line executables are included in this tutorial.

SYNTHETIC TERRAIN SOFTWARE

Would you like to make synthetic (artificial) terrain data? The following free/shareware references are for software that allows the generation of synthetic terrain data.

- GFORGE Uses an Inverse Fourier transform terrain generation technique that creates beautifully tilable, seamless terrains.

Bryce_2 This is a full 3D modeling program that also happens to include a lot of options for creation and rendering terrain. Uses a ray tracer routine to render beautifully shaded landscapes.

- Ray Dream Designer This is a full 3D modeling package that also supports terrain creation and rendering.
- Terrain Forge This software generates synthetic terrain.
- Terrain Maker Generates synthetic terrain using a classic plasma algorithm.

Created: May 14, 1997. Last updated: October 5, 1998.