

Generation of a 3D object from a Digital Elevation Model (DEM)

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06-04-2016

I Project description

1 Project overview

This report outlines the design and development of a computer software to visualize DEM files, which are from different formats, in 3-Dimensions. It allows users using several convenient functionalities such as rotations, translation, zoom along the axes, resizing or cropping using boundary boxes, creating a support at its basis to transform it into 3D object, labeling it on. The result can be exported in OBJ and STL formats.

The solution should be developed on *C++ / Qt framework*¹ and a visualisation in *OpenGL*².

2 Concepts

2.1 What is digital elevation model (DEM)?

A digital elevation model (DEM) is a digital model or 3D representation of a terrain's surface commonly for a planet (including Earth), moon, or asteroid created from terrain elevation data.

¹<http://http://www.qt.io/ide/>

²Opengl-superbible-comprehensive-tutorial-and-reference-5th-edition-2010

It is 2D map in which each point is associated with its height. DEM can be obtained through techniques such as photogrammetry, lidar, land, surveying, etc.³

2.2 DEM file formats

USGS DEM

The USGS DEM format is a standard format for the storage of raster digital elevation data. The USGS has produced five different digital elevation products with the primary differing characteristic being the spacing, or sampling interval, of the data:⁴

- 7.5-Minute DEM 30- x 30-meter data spacing
- 2-Arc-Second DEM 2- x 2-arc-second data spacing
- 15-Minute Alaska DEM 2- x 3-arc-second data spacing
- 7.5-Minute Alaska DEM 1- x 2-arc-second data spacing
- 1-degree DEM 3- x 3-arc-second data spacing

Purpose

DEM file is used in the generation of three-dimensional graphics displaying terrain slope, aspect (direction of slope), and terrain profiles between selected points. At the USGS, DEMs have been used in combination with digital raster graphics (DRG's), digital line graphs (DLG's), and digital orthophoto quadrangles (DOQ's) to both enhance the visual information for data extraction and revision purposes and to create aesthetically pleasing and dramatic hybrid digital images. Non-graphic applications such as modeling terrain and gravity data for use in the search for energy resources, calculating the volume of proposed reservoirs, and determining landslide probability have also been developed.⁵

Structure

DEM file is an ASCII file format consisting of a header record (Type A), data records (Type B) and an accuracy metadata record (Type C)⁶
The physical structure of the DEM distributed to the user is as follows:⁴

³https://en.wikipedia.org/wiki/Digital_elevation_model

⁴<http://agdc.usgs.gov/data/usgs/geodata/dem/dugdem.pdf>

⁵http://www.softree.com/Tips_Techniques/T-004-USGS-DEM/USGS_DEM.pdf

⁶<http://www.geobc.gov.bc.ca/base-mapping/atlas/trim/specs/BC-DEM-specifications-2002-12.pdf>

- Data recorded in fixed-block format on unlabeled or ANSI-labeled 9-track magnetic tape at 1,600 or 6,250 bpi density.
- Logical record size of 1,024 bytes. No more than one logical record type (A, B, or C) recorded in any 1,024-byte record. However, more than one 1,024-byte record is usually required to store a single record type B. The logical record is padded with blanks if necessary to fill to the end of the logical record. Bytes 1,021-1,024 of each logical record are padded with blanks.
- Physical record size of 4,096 bytes; that is, 4 logical records per physical record.
- Data written as ANSI-standard ASCII characters.

SDTS DEM

SDTS stands for Spatial Data Transfer Standard, is a robust way of transferring earth-referenced spatial data between dissimilar computer systems with the potential for no information loss. It is a transfer standard that embraces the philosophy of self-contained transfers, i.e. spatial data attribute, dereferencing, data quality report, data dictionary, and other supporting metadata all included in the transfer.⁷

SDTS has 7 parts. Parts 1-3 are about SDTS specification which is organized into the base specification, all of them are related, but relatively independent. Parts 4-6 are about multiple profiles, each define specific rules and formats for applying SDTS for the exchange of particular types of data in SDTS:⁸

- Part 1 Logical Specifications:
It consists of three main sections, which explain the SDTS conceptual model and SDTS spatial object types, components of a data quality report, and the layout of all SDTS modules.
- Part 2 Spatial Features:
It contains a catalogue of spatial features and associated attributes. This part addresses a need for definition of common spatial feature terms to ensure greater compatibility in data transfers. The current version of Part 2 is limited to small- and medium-scale spatial features commonly used on topographic quadrangle maps and hydrographic charts.

⁷<http://mcmcweb.er.usgs.gov/sdts/whatsdts.html>

⁸<http://mcmcweb.er.usgs.gov/sdts/standard.html>

- Part 3 ISO 8211 Encoding:

This part explains the use of a general purpose file exchange standard, ISO 8211, to create SDTS file sets (i.e. transfers).

- Part 4 - Topological Vector Profile:

The Topological Vector Profile (TVP) is the first of a potential series of SDTS profiles, each of which defines how the SDTS base specification (Parts 1, 2, and 3) must be implemented for a particular type of data. The TVP limits options and identifies specific requirements for SDTS transfers of data sets consisting of topologically structured area and linear spatial features.

- Part 5 - Raster Profile and Extensions:

The Raster Profile is for 2-dimensional image and gridded raster data. It permits alternate image file formats using the ISO Basic Image Interchange Format (BIIF) or Dereferenced Tagged information File Format (Geo TIFF).

- Part 6 - Point Profile:

The Point Profile contains specifications for use with geographic point data only, with the option to carry high precision coordinates such as those required for geodetic network control points. This profile is a modification of Part 4, the Topological Vector Profile, and follows many of the conventions of that profile.

DTED

DTED is a standard of digital datasets which consists of a matrix of terrain elevation values ⁹. It is the oldest digital mapping format that we still use today. This standard was originally developed in the 1970s by NIMA - the National Imagery and Mapping Agency. DTED was originally developed to drive 3D milling machines and provide elevation data needed for cruise missile planning. ¹⁰

DTED format have 3 level:¹¹

- Level 0
 - Has a post spacing of approximately 900 meters.
 - Elevation post spacing is 30 arc second

⁹<https://en.wikipedia.org/wiki/DTED>

¹⁰http://www.mission-planning.com/DTED_Part1.htm

¹¹<http://fas.org/irp/program/core/dted.htm>

- Derived from NIMA DTED Level 1 to support a federal agency requirement
 - DTED Level 0 may be of value to scientific, technical, and other communities for and applications that require terrain elevation, slope, and/or surface roughness information. It allows a gross representation of the Earth’s surface for general modeling and assessment activities. Such reduced resolution data is not intended and should not be used for automated flight guidance or other precision activity involving the safety of the public.
- Level 1
 - Has a post spacing of approximately 90 meters.
 - A uniform matrix of terrain elevation values with post spacing every 3 arc seconds
 - The information content is approximately equivalent to the contour information represented on a 250,000 scale map.
 - Level 2
 - Has a post spacing of approximately 30 meters.
 - He basic high resolution elevation data source for all military activities and systems that require landform, slope, elevation, and/or terrain roughness in a digital format.

DIMAP

The DIMAP stands for Digital Image Map. It is the format for SPOT products introduced for the SPOT 5 launch in May 2002 and developed with CNES.¹²

DIMAP format consists of two parts:¹²

- Image: By default it is described in GeoTIFF format, comprised of
 - A TIFF part, the most widely used image format in the world.
 - A Geo part, adding georeferencing information for the image file (coordinates in the upper left-hand corner of the image and pixel size) to the basic TIFF file and may also describe the map projection used and its corresponding geographic system.

¹²<http://www.geo-airbusds.com/en/196-the-dimap-format>

- Metadata: this is written in XML, allowing to create customized keywords with corresponding values. It can be linked to an XSL style sheet which sorts and does the HTML layout of the information contained in the XML file.

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III Software requirements

1 Functional requirements

1.1 Functional requirement 1

- ID: FR1
- TITLE: Download application
- DESC: A user should be able to download the application through our website. The application should be free to download.

- RAT: In order for a user to download the application.
- DEP: None

1.2 Functional requirement 2

- ID: FR2
- TITLE: Install application
- DESC: Given that a user has downloaded the application, then the user should be able to install this application. The user must provide direction to install by using dialog. After install, the application must notification if install success or not.
- RAT: In order for a user to install application.
- DEP: FR1

1.3 Functional requirement 3

- ID: FR3
- TITLE: Select DEM file to open
- DESC: Given that a user has installed the application, then the user should be able to open this application and open dialog to select which file will be open. There should also be a free-open DEM file option. The application must show 3D image of given file if given file format is acceptable or notification user that this file format is incorrect.
- RAT: In order for a user to open DEM file and visualize it in 3D
- DEP: FR2

1.4 Functional requirement 4

- ID: FR4
- TITLE: Rotate 3D Image
- DESC: Given that a user has open the application, then the user should be able to rotate a 3D image is being presentation by using mouse movement action. The rotate include move up, down, left, right or any angles

- RAT: In order for a user to rotate 3D image.
- DEP: FR3

1.5 Functional requirement 5

- ID: FR5
- TITLE: Zoom 3D Image
- DESC: Given that a user has open the application, then the user should be able to zoom a 3D image being presentation by double clicking mouse. The mouse clicked point must be in range of 3D image. The user is also able to minimize 3D image by hold CTRL key while click.
- RAT: In order for a user to zoom 3D image.
- DEP: FR3

1.6 Functional requirement 6

- ID: FR6
- TITLE: Select an area in 3D Image
- DESC: Given that a user has open the application, then the user should be able to select an area in 3D Image by using mouse to draw a box on the 3D Image
- RAT: In order for a user to select an area in 3D image.
- DEP: FR3

1.7 Functional requirement 7

- ID: FR7
- TITLE: Resize a boundary box on 3D Image
- DESC: Given that a user has selected an area on 3D Image, then the user should be able to resize this area by clicking right mouse and select resize. A dialog must show in order to select how many percent will be resized.
- RAT: In order for a user to select an area in 3D image.
- DEP: FR6

1.8 Functional requirement 8

- ID: FR8
- TITLE: Crop a boundary box on 3D Image
- DESC: Given that a user has selected an area on 3D Image, then the user should be able to crop this area by clicking right mouse and select crop. After cropped, the user should be able to move this area by holding left mouse and move.
- RAT: In order for a user to crop an area in 3D image.
- DEP: FR6

1.9 Functional requirement 9

- ID: FR9
- TITLE: Create a support at the basis of 3D image
- DESC: Given that a user has imported DEM file, visualized it in 3D with or without rotation, translation, zoom, resizing, cropping. The user should be able to create a support at the basis of current 3D image by clicking the "Create support" button. With the support, the 3D object should be ready to be printed by a 3D printer.
- RAT: In order for user to transform image into 3D object.
- DEP: FR3, FR4, FR5, FR7, FR8

1.10 Functional requirement 10

- ID: FR10
- TITLE: Label the 3D object
- DESC: Given that a user has created a support at the basis of 3D image. The user should be able to label the result 3D object by clicking the "Text" button, then clicking a position on the object or below its support to create text box where user can write some note as label.
- RAT: In order for user to label the 3D object
- DEP: FR9

1.11 Functional requirement 11

- ID: FR11
- TITLE: Export to OBJ, STL files
- DESC: Given that a user has created 3D object, and maybe has labeled it. The user should be able to export to OBJ or STL file by clicking the "Export" button. The appropriate format should be exported if user maintain the right filename extension (.obj or .stl). If the filename extension is not correct, then the application should throw error dialog with message "Only OBJ and STL formats supported" and end the export process.
- RAT: In order for user to export to OBJ, STL files
- DEP: FR9, FR10

2 Non-functional requirements

- Compatible operation system: Linux
- Execution speed:
 - Open DEM file or export to OBJ/STL files should be executed in maximum 10 seconds.
 - Rotate, translate, zoom, resize, crop 3D image, create support at its basis or label the object should be executed without delay.