Terrain model and gridding method variations for making topographic maps

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Abstract. The purpose of research were: (1) exploring gridding method for making topographic maps, (2) inventing terrain model that producing from 3D data, (3) structuring standard operational procedure for making topographic maps, (4) producing topographic maps from terrestrial surveying data, digital terrain model, computer aided mapping and satellite imagery, (5) evaluating topographic maps which produced. The research is using descriptive method. Universitas Pendidikan Indonesia was research location. The research was conducted on September 2017 to December 2017. Geometric calculation is used to calculate abscissa, ordinate and height information, using spreadsheet. Topographic map which was producing contour line from digital terrain model software, satellite imagery from internet, line map from computer aided mapping software could be more accurate and effective than conventional and analog method.

1. Introduction
Terrain data can be produced by three different data acquisition methods, that are topographical mapping, stereophotogrammetry and laser scanning. Digital terrain model (DTM), digital elevation model (DEM), digital surface model (DSM) and digital landscape model (DLM) are types of earth’s surface models [1].

Contour lines, profiles, regular grids (raster) and triangulated irregular networks (TIN) are four basic approaches which used to capture and and store elevation data overs intermediate or large areas. Relief is portrayed by contours. Photogrammetric analysis of stereo aerial photographs derive profiles. Elevation data are stored and analyzed by grid formats [2].

Elevation, surface shape, topographic position, topographic context, spatial scale and landform object are six important topographic factors in characterizing biophysical functions. Surface and precipitation are influenced by elevation. Steepness, slope and curvature exemplify terrain shape which influence surface and subsurface biophysical processes. Expanding windows to incorporate topographic context in terrain analysis or landform extraction have been used by researchers [3].

Modeling terrain is described a generative, probabilistic approach by researcher. The 3D spatial structure is exploited the terrain model. More accurate estimation is resulted by joint inference of ground height, vegetation height and class identity over the whole model [4]. Regularly gridded data points are converted from randomly spaced data points using triangulation with linier interpolation in the terrain surface modeling. The error propagation theory is determined for theoretical terrain surface model. The value of information loss is determined for empirical terrain surface model [5].
Propagation predictions over irregular terrains apply the parabolic equation method based on DEM. A precise representation of a three-dimensional surface with high efficiency is provided by the application of digital elevation model. Gaussian terrain profile simulation compare with the shift map in order to validate the accuracy. The resolution of the DEM used is much larger than the range step in the parabolic equation method is the only obvious prediction error [6].

The consistency, availability, cost, degree of resolution and coverage have been overcome issues of DEM generation. Various objects covered terrain is one the major issues remaining of DEM generation. Digital surface model (DSM) is provided by satellite data and converted by filtering techniques [7].

A contouring and 3D surface mapping program interpolation methods are the inverse distance to a power method, the krigging, the minimum curvature, the modified shepard’s, the natural neighbor, the nearest neighbor, the polynomial regression, the radial basis function interpolation, the triangulation with linear interpolation, the moving average, the data metrics, and the local polynomial method [8].

Spatial information are presented by topographic maps. Regional landform features on topographic maps are reflected by contour lines. Three contour lines reconstruction approaches are (i) the geometric-base, (ii) the image-base, (iii) the gradient vector flow. Four principal steps in automatic identification of contour lines on scanned topographic maps are (i) a paper map scanning, (ii) segmentation of color, (iii) the binary contour maps thinning and pruning, (iv) contour lines vectorization [9].

An essential part of height depiction in topographic maps is contours or isohypses. Visual abstraction of the earth’s surface is represented by contour. Digital elevation model (DEM) is the latest method of producing contours by a straightforward computational task without laborious manual work. Manual drawing can not be achieved likes DEM that fast automatic extraction of contour vectors with high positional accuracy and level of detail [10].

Thematic cartography tends to identify and explore cartographic style. Topographic maps are analysed from transport maps, country maps and national atlases to investigate the selection and representation of features [11].

Every aspects of public and many private sectors activities like general engineering, economic and physical planning regulation, environmental management and general planning need topographic maps as a base map for land use and land cover mapping. Most topographic maps are out of date and can not be used for desired needs. The satellite imageries were used for revising and analyzing topographic maps [12].

New methods for extraction and analysis of land elevation, automatic extraction of water bodies from the DEM were created. Vector polygons are created by polygonization utility for all connected regions of pixels in the raster sharing a common pixel value. Hydrological map topo sheets become the extracted water bodies comparation for accuracy assessment [13].

Research objective were: (1) exploring gridding method for making topographic maps, (2) inventing terrain model that producing from 3D data, (3) structuring standard operational procedure for making topographic maps, (4) producing topographic maps from terrestrial surveying data, digital terrain model, computer aided mapping and satellite imagery, (5) evaluating topographic maps which produced.

2. Methods

The survey method was used for collecting terestrial data, the geometric method was used for calculating coordinates and heights of detailed points. Gridding method was used for creating contour map and combination of satellite imagery with computer aided mapping method was used for creating topographic maps.

The survey method go through stages, namely: (1) standing theodolite on benchmark and setting nivo, (2) standing ruler on detailed points, (3) measuring and writing height of theodolite, (4) reading and writing the top, middle, bottom of ruler yarn through binoculars, (5) reading and writing the azimuth of horizontal angle through window of horizontal reading, (6) reading and writing the zenith or inclination of vertical angle through window of vertical reading, (7) finishing detailed points measurement for mapping location. Figure 1 present long section detailed points measurement.
The geometric method go through stages, namely: (1) calculating horizontal distance \( d_{AB} \), (2) calculating abscissa \( X \) and ordinate \( Y \) of detailed points, (3) calculating height different \( \Delta H_{AB} \), (4) calculating height \( Z \) of detailed points. The equation of geometric method are:

\[
d_{AB} = (BA - BB)100 \cos^2 i \quad (1)
\]
\[
X_B = X_A + d_{AB} \sin \alpha_{AB} \quad (2)
\]
\[
Y_B = Y_A + d_{AB} \cos \alpha_{AB} \quad (3)
\]
\[
\Delta H_{AB} = T_{\text{lat}} + (BA - BB)50 \sin 2i - BT \quad (4)
\]
\[
T_B = T_A + \Delta H_{AB} \quad (5)
\]

Gridding method go through stages, namely: (1) inputing abscissa \( X \), ordinate \( Y \), height \( Z \) into worksheet, (2) saving XYZ worksheet, (3) determining gridding method for XYZ worksheet, (4) calculating descriptive and inferential statistic of XYZ worksheet, (5) saving gridding report, (6) plotting contour map from gridding result, (7) exporting contour map become dxf file, (8) retrieving dxf contour map into computer aided mapping environment.

Combination of satellite imagery with computer aided mapping method go through stages, namely: (1) searching satellite imagery where location of measurement, (2) screen shooting location of measurement, (3) pointing benchmark on satellite imagery and saving as jpg file, (4) inserting jpg satellite imagery into computer aided mapping, (5) transforming coordinates of satellite imagery to Universal Transverse Mercator using Affine transformation, (6) digitizing buildings, roads network, vegetations, drainages, etc, (7) trimming and revising contour lines, (8) completing cartographic components, (9) eliminating satellite imagery, (10) printing topographic map.
3. Result and Discussion

3.1. Conceptual, Functional Model and Implementation of Gridding Method

The conceptual model presents the linkage between the resulting feature and the graphic data base. Gridding method produces 6 main features, namely: base, contour map, post, 3 D surface, color relief, specialty and 14 additional sub-features, namely: base, base from data, base from server, empty basemap, post, classed post, 3 D surface, 3 D wireframe, shaded relief, grid values, watershed, 1 grid vector, 2 grid vector, point cloud. The most graphic data base is a point symbol with 9 usages, line with 5 usage, shade with 5 usage and polygon with 3 usage.

| No. | Features     | Sub-features       | Point | Line | Polygon | Shade |
|-----|--------------|--------------------|-------|------|---------|-------|
| 1.  | Base         | Base               | v     | -    | -       | -     |
|     |              | Base from data     | v     | -    | -       | -     |
|     |              | Base from server   | v     | -    | -       | -     |
|     |              | Empty base map     | -     | -    | -       | -     |
| 2.  | Contour map  | Post               | -     | v    | v       | -     |
| 3.  | Post         | Post               | v     | -    | -       | -     |
|     |              | Classed Post       | v     | -    | -       | -     |
| 4.  | 3D Surface   | 3D Surface         | -     | -    | -       | v     |
|     |              | 3D Wireframe       | -     | v    | v       | -     |
| 5.  | Color relief | Shaded relief      | -     | -    | -       | v     |
|     |              | Grid values        | v     | -    | -       | -     |
|     |              | watershed          | -     | v    | v       | v     |
|     |              | 1 Grid vector      | v     | v    | -       | -     |
|     |              | 2 Grid vector      | v     | v    | -       | -     |
|     |              | Point Cloud        | v     | -    | -       | v     |
| Total|              |                     | 9     | 5    | 3       | 5     |

The functional model presents the relationship between features with 2 dimensional coordinate system and 3 dimension from the result of descriptive and inferential statistical analysis. Functional model shows that the presentation of 2 dimensional modeling gridding method as much as 13 views while 3 dimensional representation of 3 views. The creation of situation and topographic maps is presented in 2 dimensions to obtain geometric information of distance, angle and area.

| No. | Features     | Sub-features       | 2-dimensional presentation | 3-dimensional presentation |
|-----|--------------|--------------------|----------------------------|----------------------------|
| 1.  | Base         | Base               | v                          | -                          |
|     |              | Base from data     | v                          | -                          |
|     |              | Base from server   | v                          | -                          |
|     |              | Empty base map     | v                          | -                          |
| 2.  | Contour map  | Post               | v                          | -                          |
|     |              | Classed Post       | v                          | -                          |
| 3.  | Post         | Post               | v                          | -                          |
|     |              | Classed Post       | v                          | -                          |
| 4.  | 3D Surface   | 3D Surface         | -                          | v                          |
|     |              | 3D Wireframe       | -                          | v                          |
| 5.  | Color relief | Shaded relief      | -                          | v                          |
|     |              | Grid values        | -                          | v                          |
|     |              | watershed          | -                          | v                          |
|     |              | 1 Grid vector      | v                          | -                          |
|     |              | 2 Grid vector      | v                          | -                          |
|     |              | Point Cloud        | v                          | -                          |
| Total|              |                     | 13                         | 3                          |
Implementation gridding method contain 9 phases, that are (1) tachymetri measurement, (2) contour line made and detailed points, (3) contour line presentation and detailed points, (4) satellite imagery of measurement location, (5) benchmarks pointing on large scale of satellite imagery of measurement location, (6) presentation of large scale of satellite imagery of measurement location with benchmarks, (7) digitizing natural and man made borders, (8) editing contour line, (9) topographic map presentation.

### Table 3. Implementation of Gridding Method

| No. | Activity                                                      | Input data                                                                 | Output data                                                                                      | Software          |
|-----|---------------------------------------------------------------|----------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|-------------------|
| 1.  | Tachymetri measurement                                       | X,Y, Z benchmark, $T_{\text{instrument}}$, $\alpha_{ij}$, Inclination, BA, BT, BB | X, Y, Z of detailed points                                                                      | MS Excell        |
| 2.  | Contour line made and detailed points                        | X,Y, Z of detailed points                                                  | Contour line and post map                                                                        | Golden Surfer     |
| 3.  | Contour line presentation and detailed points                 | Contour line and post map                                                  | Contour line and post map                                                                        | Autodesk Map      |
| 4.  | Satellite imagery of measurement location                    | Measurement location                                                       | Large scale of satellite imagery of measurement location                                         | Google Earth      |
| 5.  | Benchmarks pointing on large scale of satellite imagery of measurement location | Large scale of satellite imagery of measurement location                    | Large scale of satellite imagery of measurement location with benchmark                          | Paint Brush       |
| 6.  | Presentation of large scale of satellite imagery of measurement location with benchmarks | Large scale of satellite imagery of measurement location with benchmark    | Large scale of satellite imagery of measurement location with benchmark in UTM coordinates      | Autodesk Map      |
| 7.  | Digitizing natural and man made borders                      | Large scale of satellite imagery of measurement location with benchmark in UTM coordinates | Vector format line map of measurement location in UTM coordinates                               | Autodesk Map      |
| 8.  | Editing contour line                                          | Vector format line map of measurement location in UTM coordinates           | Contour lines which resulted by editing works appropriated to the rule of contour lines          | Autodesk Map      |
| 9.  | Topographic map presentation                                 | Contour lines which resulted by editing works appropriated to the rule of contour lines | Digital topographic map                                                                        | Autodesk Map      |

3.2. **Map of Digital Contour and Satellite Imagery Overlay**

Map of digital contour and satellite imagery contain 3 layers, that are (1) contour map from Golden Surfer software, (2) satellite imagery map from Google Earth, and (3) natural and man made detailed digitizing from Autodesk Map. All layers were tied by 48 zone UTM coordinates. Coordinate transformation used Affine method which transformed satellite imagery screen shoot to UTM.
3.3. **Map of Digital Contour and Digitizing Overlay**

Map of digital contour and digitizing overlay contain 2 layers, that are (1) contour map and post map from Golden Surfer software, (2) natural and man made detailed digitizing from Autodesk Map. All layers were tied by 48 zone UTM coordinates. Coordinate transformation used Affine method which transformed satellite imagery screen shoot to UTM.
4. Conclusion

A contouring and 3D surface mapping program interpolation methods are the inverse distance to a power method, the krigging, the minimum curvature, the modified shepard’s, the natural neighbor, the nearest neighbor, the polynomial regression, the radial basis function interpolation, the triangulation with linear interpolation, the moving average, the data metrics, and the local polynomial.

Gridding method produces 6 main features, namely: base, contour map, post, 3D surface, color relief, specialty and 14 additional sub-features, namely: base, base from data, base from server, empty basemap, post, classed post, 3D surface, 3D wireframe, shaded relief, grid values, watershed, 1 grid vector, 2 grid vector, point cloud.

Implementation gridding method contain 9 phases, that are (1) tachymetri measurement, (2) contour line made and detailed points, (3) contour line presentation and detailed points, (4) satellite imagery of measurement location, (5) benchmarks pointing on large scale of satellite imagery of measurement location, (6) presentation of large scale of satellite imagery of measurement location with benchmarks, (7) digitizing natural and man made borders, (8) editing contour line, (9) topographic map presentation.

Map of digital contour and satellite imagery contain: (1) contour map, (2) satellite imagery map, (3) natural and man made detailed digitizing. All layers were tied by 48 zone UTM coordinates. Coordinate transformation used Affine method which transformed satellite imagery screen shoot to UTM.
Map of digital contour and digitizing contain: (1) contour map and post map, (2) natural and man made detailed digitizing. All layers were tied by 48 zone UTM coordinates. Coordinate transformation used Affine method which transformed satellite imagery screen shoot to UTM.

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