3D Terrain Modelling of the Amyntaio – Ptolemais Basin

G. Argyris, I. Kapageridis and A. Triantafyllou

Department of Geotechnology and Environmental Engineering, Technological Educational Institute of Western Macedonia, Greece; E-mail: ikapa@airlab.teikoz.gr

ABSTRACT

A number of important studies, ongoing environment monitoring efforts and mining and road construction projects in the lignite based electrical power production area of Amyntaio – Ptolemais in North West Greece require an accurate and up to date model of the topography. In recognition of the importance of such a model, a project was initiated by the Laboratory of Mining Information Technology and GIS Applications in the Department of Geotechnology and Environmental Engineering of the Technological Educational Institute of Western Macedonia. A massive surface triangulation model was generated from vector data using an optimized Delaunay based method. Combined with aerial and satellite imagery, the triangulation model provides a complete 3D terrain model of the area characterized by high levels of accuracy, detail and realism. The generated model is easy to modify with new data in order to improve its detail and keep it up to date with ongoing earth moving and development operations in the area.

1. PROJECT AIMS

The project aims at the generation of a large terrain model of the wider area of North-West Greece in the EGSA87 coordinate system that can be used by a variety of computer software (CAD, GIS, Modeling) and hardware (PC, PNA, etc). This model will be used as the basis for a number of studies including air pollution modeling and resource/reserves calculations for lignite deposits in the area. The currently completed terrain model covering the area of Amyntaio and Ptolemais can be downloaded from the Laboratory of Mining Information Technology and GIS Applications web site http://airlab.teikoz.gr/geope/labs/mineitlab.htm and in multiple formats (DEM, DXF, DWG, Vulcan™ Triangulation).

2. MAP SCANNING AND IMAGE PROCESSING

2.1 Scanning

The data collection process involved scanning and digitizing existing maps, produced by the Hellenic Military Geographical Service, using specialized hardware and software. A professional drum scanner, the Kip Starprint 6000, was used for map scanning. The scan resolution was 400 DPI resulting in each map occupying 200 to 250 Mb of disk space. The scanned maps were stored in Tagged Image File Format (TIFF). This format is ideal for high quality digital imagery when disc space and computer memory is not an issue. If file size is an issue, TIFF supports lossless compression.

2.2 Image Processing

Image processing was performed in Adobe Photoshop™. In order to convert the raster images from the scans to vector maps that can be modelled, it is necessary to convert the images to bitonal (black and white - 1 bit colour depth). This is achieved by applying a threshold value to the colour pixels based on their brightness. In other words, pixels brighter than the threshold are converted to white (value = 1) while pixels darker than the threshold are converted to black (value = 0). The choice of threshold value depends on the image histogram and can only be
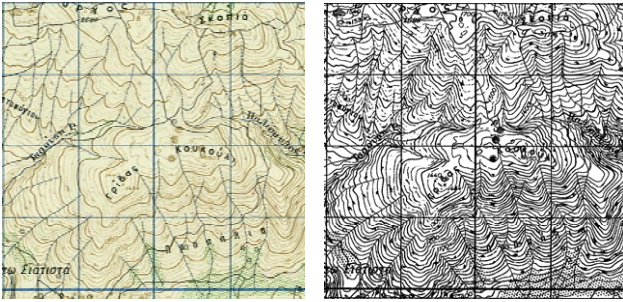
Figure 1: Converting a colour scan to a bitonal image using a threshold brightness value.

fixed by trial and error until the resulting contours in the bitonal image are clear enough for vectorization (Fig. 1).

The bitonal images were inverted leading to white contours and black background and cleaned using a Despeckle operation to remove unwanted clusters of pixels.

3. GEOREFERENCING

3.1 Image Insertion to Real World Coordinates

Once the raster maps were ready, they were inserted into an AutoCAD™/Raster Design™ drawing. A Match operation was performed, which applies linear correlation, adjusting insertion point, scale and rotation as necessary, to align the raster maps with known points in the vector drawing. To match the raster maps to real world coordinates in a drawing, two source points were selected on the raster map and two corresponding destination real world coordinate points in the drawing. Raster Design™ uses these points as a reference to reposition the image relative to the drawing (Autodesk, 2005). The raster map points selected in each map were located diagonally (lower left and top right corner) on the coordinate grid lines of the map were the coordinates are known, while the destination points were the actual real world coordinates as shown on the map.

3.2 Rubbersheeting

The point matching procedure performed right after the raster map insertion into a vector drawing is not sufficient to bring all points on the map to their true real world coordinates (Argyris, 2008). This was particularly important in this project as the source maps were in the HATT projection system which is not orthogonal and their coordinate grid lines are not paral-

lel to each other. In order to bring the entire raster map to the correct coordinates, a very useful Raster Design™ tool was used called Rubbersheeting. Rubbersheeting uses a set of matched control points, consisting of source points in the raster map and destination points in the drawing. These points can be specified by establishing a grid of destination points, to which the source points are matched. In this case, the grid of destination points represented the points of intersection between actual coordinate grid lines shown in each map (Fig. 2). A total of 588 grid points per map were matched to control points (28 horizontal x 21 vertical coordinate grid lines). Once these control points were established, the raster maps were transformed so that the points align as closely as possible. There are two transformation methods that can be used to correct the raster map:

- The Triangular Method draws a series of triangles between the control points, and then applies the transformation to those areas. This process uses the Delaunay triangulation method in which no point lies inside the circle that includes the vertices of any triangle.
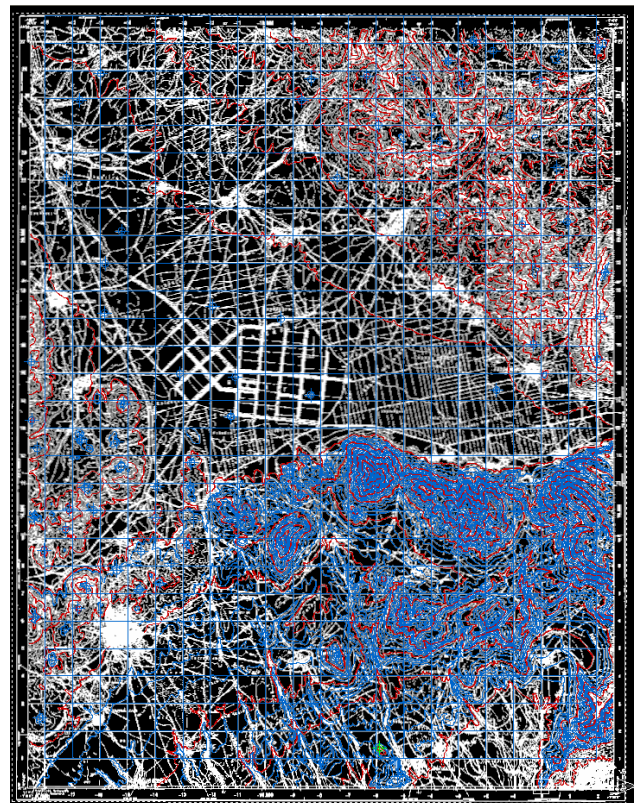

Figure 2: Screenshot from Raster Design™ showing a raster map of Kozani with rubbersheet grid lines and traced contours.

Each triangular area is transformed separately, so this method is much more accurate than the polynomial method, but can result in the loss of some image data. The area to be transformed, called the convex hull, is defined by the outermost destination points. Image data outside the convex hull is discarded.

- The Polynomial Method transforms the entire image to match, as nearly as possible, the control points you specify. Unlike the triangular method, however, the actual destination points do not always match the destination points you selected. The resulting error is expressed as a numerical value in the Rubbersheet dialog box, and is displayed graphically on the image after the control points have been entered. The error for each point is measured as a distance from the intended point to the actual point.

By adjusting the polynomial degree, the accuracy of the matching points is increased. However, reducing the error can create a higher degree of warping in the image as it is transformed to match the control points. Therefore, the lowest possible polynomial degree should be used that will still give an acceptable result. Higher polynomial degrees result in smaller errors at the control points, but also result in more warping at places where there are no control points. The polynomial method was used as it was impossible to use the triangular method with such a high number of control points due to software limitations.

4. 3D CONTOUR TRACING

Major and minor contours from the raster maps were traced using a special contour follower tool in Raster Design™. This tool provides a semi-automated procedure for contour tracing in three dimensions giving more control to the user over other fully automatic raster to vector conversion packages. The user adjusts parameters such as major and minor contour interval, layer allocation, and digitized contour line properties. Contours are traced one by one and once a contour is completely traced the user verifies or modifies the calculated contour elevation. The user can choose to work in the direction of increasing or decreasing elevation, and the soft-
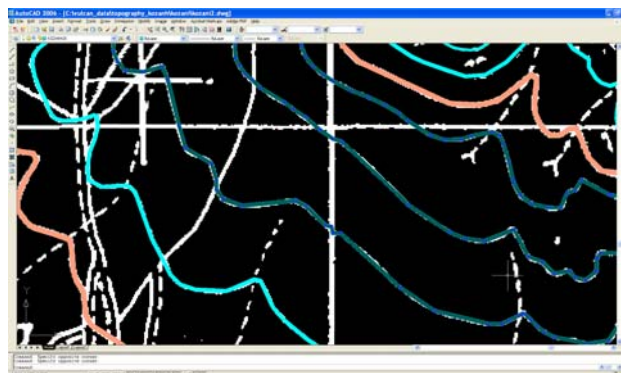

Figure 3: Traced contour lines in Raster Design™.

ware adjusts the increments or decrements of elevation to make suggestions as to the elevation of each new contour being traced. The user has to manually overpass features such as elevation labels and also direct the tracing to the correct branch in cases of intersecting lines. The whole process is fairly time consuming but the end result is a set of very accurate, high resolution 3D contour lines (Fig. 3).

5. HATT TO EGSA87 TRANSFORMATION

As the maps were positioned orthogonally while maintaining their original coordinates, it was necessary to transform them into the current EGSA87 system. The contours from Raster Design™ were exported to a DXF file and then imported into Vulcan 3D™ software for further processing and modeling. A scaling and translating transformation matrix was calculated for each map. Vulcan's Calculate option was used that allows the creation of transformation matrices that can then be used to transform data. The transformation matrix was based on point data (original and transformed points) in an ASCII file. The transformations produced are best-fit affine (linear) transformations (Maptek, 2007). 3D transformation matrices were produced for each map using eight points, four original coordinate triples and four transformed coordinate triples. The transformed contour layers were saved into a vector database in Vulcan. A report was produced for each transformation showing the RMS error (Fig. 4).

The transformed maps showed a much better agreement close to their common boundaries than the original (Fig. 5).
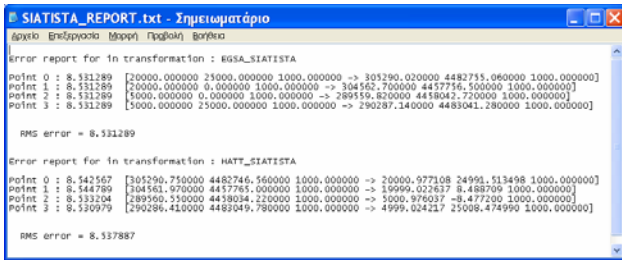
Figure 4: Transformation report from the map of Siatista showing control points and RMS error.

6. TRIANGULATION SURFACE MODELLING

The EGSA87 contour lines from all maps were used to generate an optimized Delaunay triangulation model. The contour lines were used as breaklines for the triangulation algorithm. Special filtering of long-edged and small-angle triangles was performed along the outer boundaries of the model to remove triangles linking very distant points.

The algorithm was optimized by the calculation of *spur strings*. Spur strings represent the natural breaklines that form at the top of the hills and the bottom of valleys. Spur strings are incorporated into the triangulation model to keep these areas from being flat. This forces the triangula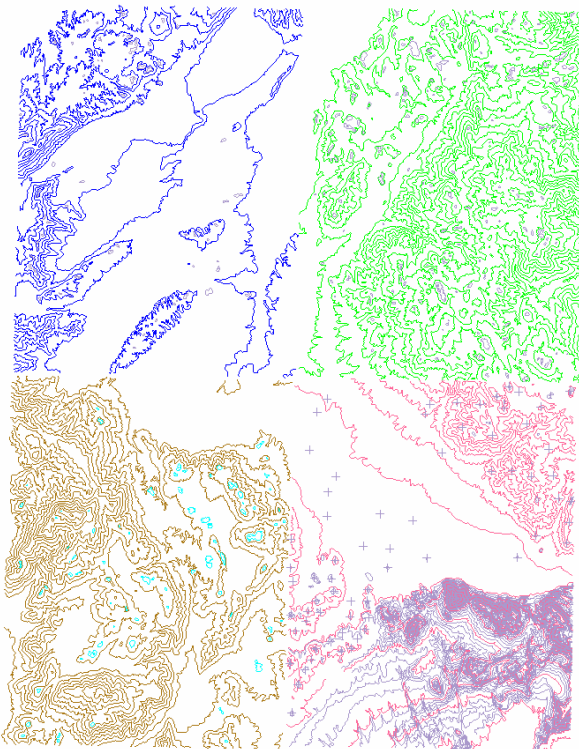tion to triangulate between contour lines in places where it may triangulate between points on the same contour line (Fig. 6). Vulcan™ can also apply a value to the centre point of the spurs generated across a flat area that is totally enclosed by a contour (e.g. a summit). It attempts to assess the contour interval from the data and then applies +/- 0.5× this assessed interval to the centre point of the spur strings. If the data being triangulated are not contours and/or the strings do not have the same Z values at all points (like a contour does) the effect of this option is not always predictable.

The generated triangulation model was solid shaded, smoothed and colored using an elevation based scheme (Fig. 7).

The complete triangulation model of the area currently covered included 338,458 nodes and 533,105 triangle faces. The final model of the entire North West Greece is estimated that, once completed, will consist of over 2 million triangle faces.

7. INCORPORATION OF SURFACE WORKINGS

Data from several vector maps collected by conventional surveying and digital photogrammetry of existing lignite mine pits were incorporated

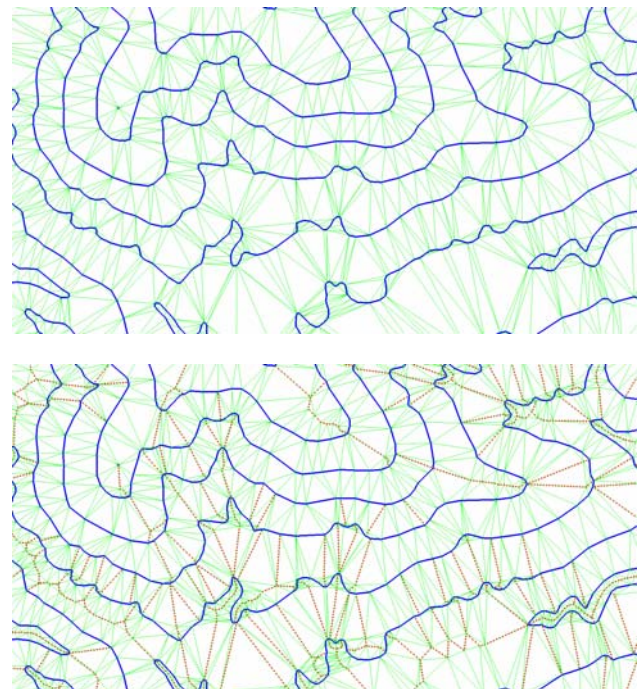Figure 5: Maps of Pyrgoi, Siatista, Ptolemaida and Kozani after transformation to the EGSA87 system.

Figure 6: Normal triangulation (top) and optimized triangulation (bottom) showing the elimination of flat spots using spur strings (dotted lines).
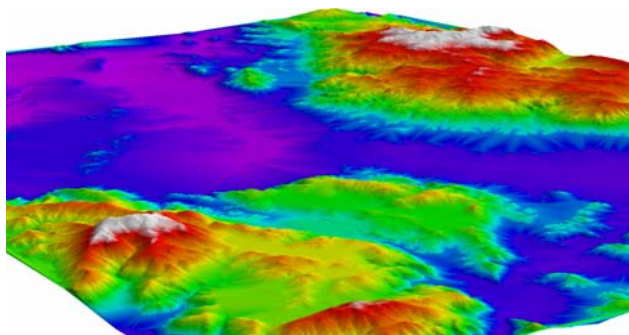
Figure 7: 3D perspective view of the generated model looking north east.

Figure 8: Triangulation model of excavation and surrounding area partly textured using a satellite image from Google Earth™.

into the digitized data to generate a more realistic and updated view of the area. All vector maps were converted to EGSA87 before their insertion to the natural topography contours. Each excavation was modeled using the standard Delaunay triangulation algorithm. Spur strings were not calculated for the excavation surfaces as these are not natural and the incorporation of spur strings would alter their geometry. The boundaries of each excavation surface had to be digitized in order to cut out the natural topography model prior to inserting an excavation surface model.

8. AERIAL PHOTOGRAPHY DRAPING

Several images of the lignite production area of Amyntaio and Ptolemais were collected from Google Earth™, georeferenced in EGSA87 coordinates and draped on the triangulation model using Vulcan™. These images are low resolution and not always up to date and were used only to show the potential of image draping. Georeferencing these images included nominating control points that could be approximately located on both the images and the underlying triangulation model. The model was thus textured with the image. The image colors can be combined with the triangulation shading and coloring to improve the realism of the model (Fig. 8).

9. CONCLUSIONS

The need for an up to date model of the topography is common in many studies and applications. The lignite production area of Amyntaio-Ptolemais is constantly monitored for its air pollution levels and explored for new lignite production areas. The availability of a complete ter-
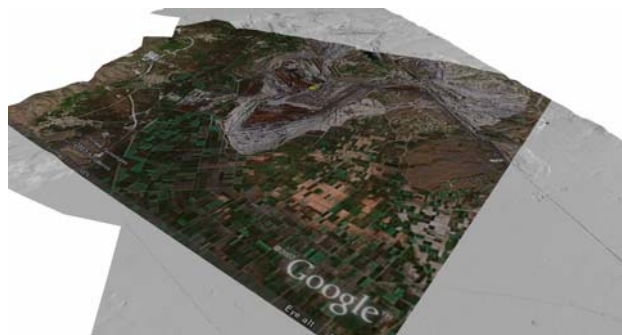
rain model that can be used by these and other applications is crucial. The project described in this paper was realized to cover this need. The procedure described involves different software packages that work well together to produce an accurate, easy to update model that can be imported and used by other CAD, GIS and modeling applications.

REFERENCES

Argyris, G., 2008. Map Digitizing and Construction of a 3D Digital Terrain Model of the Amyntaio-Ptolemais Area. Final year thesis, Department of Geotechnology and Environmental Engineering, School of Technological Applications, Technological Educational Institute of Western Macedonia, Kozani.

Autodesk, Inc., 2005. Raster Design 2006 Getting Started Guide.

Maptek Pty Ltd, 2007. Vulcan 3D Software Online Help.