Creation of a virtual landscape of Al-Madinah Al-Munwwarah in Saudi Arabia including 3-dimensional scene attributes

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ABSTRACT: This paper investigates the suitability of remotely-sensed data as the main source of information to generate virtual topographic features of Al-Madinah Al-Munwwarah in Saudi Arabia. A number of airborne and spaceborne data sources have been considered. These include aerial photographs at scale 1:5000, orthophotographs at scale 1:10000, and SPOT (Pan, XS). Remotely-sensed data has been used to create a digital elevation model (DEM) and, separately, a tablecloth has been derived to drape over the DEM. The resultant DEM, and associated imagery, have been imported into 3D Studio Max software in order to add several attributes to the scene and to support fly-through of the scene model.

1 INTRODUCTION

Three-dimensional terrain data is important for planning and exploration purposes, especially in developing countries. In response to this need the number and resolution of airborne and spaceborne data sources are increasing. The use of 3-dimensional computer graphics is commonplace in all areas of life today. Because most humans are able to see in three dimensions, a three dimensional (3D) representation of reality may improve our ability to interpret two-dimensional (2D) imagery; viewing images in 3-dimensional perspective may also contribute to increased understanding of features and their relationships in data sets (Toutin, 2001). It is possible to create a 3D model — a Digital Elevation Model (DEM) — from remotely-sensed data, facilitating the visualisation of these data to promote the accessibility of earth observation information for everyday use. Fly throughs of these DEMs take these developments a step further by allowing users to visualise computer generated landscapes. Engineers, cartographers, geologists, hydrologists, and other geo-scientists use different 3D viewing methods in order to better understand the Earth surface (Toutin, 2001).

There are different possibilities for the generation of DEMs, such as by classic ground measurement, stereo-photogrammetric measurement from aerial photographs, or from stereo satellite images such as SPOT, optical laser measurements, digitisation of contour lines from maps, LiDAR sounding, or other ranging measurements.

In this paper contour lines from digital topographic maps at scale 1:1000 are used to produce a DEM. Later, the DEM produced was imported into 3D Studio Max software in order to add texture and several attributes to the scene and to visualise flying through the model. The intention is to allow a wider user audience to make use of remotely-sensed spatial information in their applications.

2 LOCATION AND STUDY AREA

Al-Madinah Al-Munwwarah is located in the northwestern part of the Kingdom of Saudi Arabia to the east of the Red Sea see figure (1). Al-Madinah is surrounded by a number of mountains: Al-Hujai or Pilgrim’s mountain to the west, Sala’ to the northwest, Al-E’er or Caravan Mountain to the south, and Ohud’s mountain to the north. Al-Madinah is situated on a flat mountain plateau at the junction of the three valleys of Al-Aqil, Al-Aqiq, and Al-Himdah. The city is 620 meters (2,046 ft) above sea level. Its western and southwestern parts have many volcanic rocks.
3 OBJECTIVE

The objective of this study is to investigate the utility of remotely-sensed data as the main source of information for the generation and visualisation of virtual topographic features. A DEM of Al-Madinah city in Saudi Arabia has been created and used to produce a synthetic landscape by means of various digital image processing techniques such as: georeferencing, mosaics, data fusion, enhancement and filtering. Different data sets have been used in this project, as indicated in section 4.

The end result includes animated fly-through sequences of the completed model to demonstrate the utility and capabilities of this type of work.

4 DATA USED

The data used for this study were:
- Digital topographic maps at scale 1:1000.
- Panchromatic aerial photographs at scale 1:5000.
- Orthophotographs at scale 1:10000.
- SPOT (PAN, XS) satellite images.

The images were geometrically corrected to the 1:1000 digital topographic base.

5 METHODOLOGY

This project focused on the creation of a DEM using various sources including topographic maps, aerial photographs, and space imagery. The resultant DEM and associated imagery were imported into 3D Studio Max software to allow the modification of scene content to include real landscape attributes. Figure (2) shows a schematic diagram of the procedures carried out in this paper.

The main work phases that have been addressed include:
- Derivation of the DEM from remote sensing data: this includes the use of image processing packages for the estimation of topographic features and the construction of the DEM from digital topographic map at scale 1:1000.
- Georeferencing the overlay data: these data sets were mapped to the Universal Transverse Mercator (UTM) reference projection.
- Superimposing satellite images and air photographs onto the digital elevation model using different packages including ER Mapper, PCI, AutoCAD, MicroStation, MapInfo, Internet Space Builder, VrmlPad, 3D Studio Max and Vertical Mapper to drape satellite imagery over the DEM for landscape visualisation purposes.
- Creation of an animated fly through: a video trailer has been produced, together with a VRML model, with AVI and MPEG sequences that are available on the web. The individual frames of the animation have been rendered and combined to produce animated sequences. As part the rendering process, texture and lighting have been added in order to create a realistic scene.
- Addition of 3-dimensional scene attributes identified in the digital topographic maps such as: buildings, mosques, and street lamps have been inserted onto the DEM.
- Regeneration of the landscape to include scene attributes: the landscape has been regenerated with the new scene attributes included as 3-dimensional structures in appropriate locations.
- Establishment of a processor farm for scene rendering: a network of computers has been set up to allow individual frames to be rendered and assigned to different network nodes in order to reduce the rendering time.
- Finally, animated fly through sequences of the completed model have been produced to demonstrate the capabilities of this work.
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6 DEM CONSTRUCTION

Digital topographic maps of 1:1000 scales have been used to create a digital elevation model with a height interval of 1 meter. Digital topographic maps in DGN format were opened using MicroStation software to knit them together seamlessly. The output was then exported in DXF format to Vertical Mapper to create the DEM using the Triangular Irregular Network (TIN) interpolation method. The TIN interpolation technique uses a network of triangular faces, drawn as possible links connecting the points in the data set, to estimate the values at each grid node. The DEM was then exported to DXF format as a mesh. The mesh could then be imported into the 3D Studio Max visualisation software to generate the landscape.

7 DIGITAL IMAGE PROCESSING

Four different sets of remotely-sensed data have been investigated, as indicated in section 4, with personal knowledge and field checks used to recognise the features in this area. Interpretation has been assisted by using image processing techniques available within the image processing software packages used. The software packages used in this study are mentioned in section (5). The analysis of the remotely-sensed imagery and its integration with digital spatial data consisted of the following three steps:
1. A digital topographic map of 1:1000 scale was used as the reference.
2. Aerial photographs, orthophotographs, SPOT (PAN, XS) were registered with the digital topographic map and resampled using nearest neighbour resampling.
3. Data fusion methods were used to improve the spectral information for the visualisation of the topographic features.

7.1 Data fusion

Data fusion is simply the integration of multiple data sets. A general definition of image fusion is given as “the combination of two or more different images to form a new image by using a certain algorithm” (Pohl and Genderen, 1998). The reason for using data fusion is to improve the interpretability of images. Interpretability was improved by using image processing to combine multi-source imagery to reveal all the possible information to obtain the maximum image quality and increase the reliability of the interpretation of these images. Since the aerial photographs used in this study are panchromatic, SPOT XS data has been fused to provide colour information to the landscape.

7.1.1 Results

Six fused colour images were created using three methods. Table (1) indicates the image combinations used to produce figures 3, 4, 5, 6, 7, and 8.

Table 1. Data fusion methods

<table>
<thead>
<tr>
<th>Image Combination</th>
<th>RGB &amp; I Fusion</th>
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8 SOFTWARE TRAINING AND MODEL GENERATION

8.1 3D Studio Max R2

The 3D Studio Max software package is dedicated to 3D modeling and animation. It is used in a wide variety of industries from entertainment to architecture. The 3D Studio Max software enables the user to generate realistic landscapes ranging from everyday environments and objects for commercial and industrial purposes, to those of fantasy worlds created for use in films, or for use as still images.
Figure 3. RGB & Intensity fusion of Aerial Photograph with SPOT (XS)

Figure 4. Brovey fusion of Aerial Photograph with SPOT (XS)

Figure 5. RGB & Intensity fusion of Orthophotograph with SPOT (XS)

Figure 6. Brovey fusion of Orthophotograph with SPOT (XS)
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8.2 **Importing DEM into 3D Studio Max**

As mentioned in section 6, the DEM was created in Vertical Mapper, and then exported to 3D Studio Max in AutoCAD DXF format. 3D Studio MAX incorporates an import filter for importing DXF files, so importing the data is straightforward, if somewhat time consuming. The DXF file is then saved as a 3D Studio Max file. To improve the appearance of the terrain in figure (9), relief shading can be applied to the DEM. At the most basic level relief shading merely consists of some unevenness to make the terrain appear more natural, and to break up the large solid-coloured flat areas, see figure (10).

Relief shading assists the viewer to judge distances on the surface of the land. However, for many applications the viewer needs more than the shape of the land for reference. Viewers need to know where they are, and more importantly, the location of certain features on the terrain. Landscape features might include roads, buildings, rivers, fields, bridges, etc.

There are three ways of adding these features to the terrain:

1. The simplest is to simply lay a feature map over the terrain (Connolly, 2000). This is easy to do as digital feature maps can be obtained from the same sources as the DEM. This method has the advantage that it is easily understandable and many important features will be labeled. However if visual ap-
appearance is important then this model is clearly not suitable.
2. The next approach is to take an aerial photograph, or a satellite image of the terrain and lay it down over the model (Waugh, 1999). This produces a better result as the viewer can see what the landscape actually looks like and where everything is, but only when the viewer is looking down from above the surface on the land. As the photo is two-dimensional, the model is less helpful for close to ground work.
3. The last and most complex method is to build a 3-dimensional model of every object in the scene, and texture them accordingly. In this paper aerial photographs and 3-dimensional scene attributes have been used.

8.3 Adding Aerial Photographs

By using aerial photographs, it is possible to generate a 3D-terrain model, and to view the in situ location of every feature on the land. Furthermore, with careful choice of camera locations it is possible to create a very realistic image or video of the terrain. In this study a 2km × 1.5km terrain model has been produced. The overlay used was created by stitching sections from three aerial photographs together and then fusing these with satellite imagery to create the final version. Sample views of the terrain with the fused image overlaid are shown in figures 11, and 12 (a & b).

8.4 Other Improvements

There are a number of other enhancements that can be made to give the viewer a better idea of where they are and what they are looking at. These enhancements also contribute to improving the realism of the scene. These enhancements include the addition of a synthetic sky, and realistic illumination. While adding a sky to the scene may seem just a way of making it more aesthetically pleasing, when added to an animated scene it can be very useful as it gives the viewer an improved frame of reference. For example if the camera turns, the viewer will have a more accurate impression of how far the camera has moved, and what they are looking at now compared with what they were looking at before, see figure 13.

8.5 Addition of Scene Attributes

The inclusion of 3-dimensional scene attributes such as buildings, mosques, trees, etc. into the landscape is an aim in this study. These attributes have been
identified in the digital topographic maps then placed in appropriate locations. The textures have been collected in the course of field work and applied to add realism to the landscape, figure 14,15.

CONCLUSION

This study demonstrates some utility of remotely-sensed data as a resource for the creation and visualisation of virtual landscapes. In this paper, a DEM has been created using the TIN interpolation method, and then used to produce a synthetic landscape. Different overlay data sets have been examined including digital topographic maps at 1:1000 scale, panchromatic aerial photographs at scale 1:5000, orthophotographs at 1:10000 scale, and SPOT (PAN, XS) satellite imagery. The resultant DEM, and associated data, have been imported into 3D Studio Max software in order to add several attributes to the scene and to support fly-through of the scene model. The principal difficulty lies in building suitable 3-D models for the scene attributes to be rendered. A video trailer has been produced, together with VRML model and AVI and MPEG sequences that are available on the web.

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