Unlocking Historic Landscapes in the Eastern Mediterranean: data processsing

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Outline

This document details the approaches and methods used during this project in order to process both historic aerial photography, and satellite imagery.

Data source description

In order to complete the project, comparisons between newly acquired and historic data sources was necessary. Historic data included aerial photography acquired from The Aerial Reconnaissance Archive (TARA) at Keele University. However this data could only be obtained for the Naxos, Greece, study region. The raw data was supplied via FTP service by Mr A Buchholz of TARA.

The newly acquired data used for comparative purposes included the following:

- 30 metre digital elevation model data for Naxos, Greece (approximately 241km^2) and Thrace, Turkey (approximately 215km^2) generated from Soviet Military Mapping at 1:50,000 used for the orthorectification process for satellite imagery. This data was supplied in standard ESRI ArcGIS compliant ArcGrid format.

- Soviet Military Mapping at 1:50,000 scale used for ground control due to the lack of ground survey data for both historic and newly acquired data. This data was supplied in standard GeoTIFF format. The data was supplied in the following projection systems:
    - Naxos, Greece – Universal Transverse Mercator Projection Zone 35S
    - Thrace, Turkey – Universal Transverse Mercator Projection Zone 35T

- IKONOS Geo Ortho Kit Imagery Products were ordered from European Space Imaging for both Naxos, Greece, and Thrace, Turkey. Geo Ortho Kit is supplied complete with camera geometry captured during image collection, so that the photogrammetric processes can be completed manually. This data was supplied in 4 multi-spectral bands (Red, Green, Blue, Near-Infrared) as well as a pan-chromatic band offering up to 1m spatial resolution. All imagery was collected with maximum 20% cloud cover and a minimum 60° collection angle.

Software

Throughout the completion of the processing of the afore mentioned data sources, standard Windows compatible software was used including Microsoft Office to detail processing procedures carried out. Environmental Systems Research Institute (ESRI) ArcGIS including ArcMap 9.1 and ArcCatalog 9.1 were used to visualise both pre and post processed data sets. In addition, in order to perform the geo and orthorectification processes necessary, Leica GeoSystems Erdas Imagine 8.7 and 9.0 were incorporated into the workflow.

Data processing techniques

The next section will give an overview to the terms and techniques utilised when processing both the historic and newly acquired satellite imagery. It will specifically deal with the following:

- Geo-referencing
- Rectification
    - Resampling
- Ortho-rectification

This section will detail each of the approaches taken during data processing, highlighting the necessity to use such approaches due to varying factors including; time consumption, processing power availability, availability of comprehensive metadata, availability of ground control, and finally with respect to any previously applied data processing techniques. The information given in places will make specific reference to some datasets used. Initially, a brief overview of the techniques used will be included.

Geo-referencing – overview of procedure

The georeferencing technique involves assigning real-world known absolute coordinates to a data set, and therefore applying a particular coordinate reference system to the dataset. The locations of the real world absolute coordinates can come from a variety of sources, either another pre-georeferenced image, a map, but are often from a ground control survey, as these can provide the most accurate results. The points selected are termed ground control points (Campbell 2002) and the purpose of this technique is to compute an image to world transformation matrix that defines the relationship between the input image and output image (Campbell 2002).

The selection of these ground control points, whether from another image, map or pre-defined based on a survey undertaken, should:

- Be visible all year round (temporally stable);
- Usually be man-made i.e. a road junction or bottom of building
- Be visible in both image to be rectified, as well as the pre-georeferenced data source.
- Be in areas of high contrast in the imagery

(Schowengerdt 2007)

Rectification and resampling

The process of transforming from the image system i.e. rows and columns of pixels in a regular pattern, to the desired world coordinate system, is known as rectification. To complete this process, a resampling technique must be assigned in order to transform each pixel to a new location within the image, representing the corresponding point in the real world. Essentially, the pixels are redistributed throughout the original image to represent the original image in its new georeferenced location.

There are generally considered to be three commonly used types of image resampling technique, and they are:

- **Nearest neighbour** – this takes the closest input pixel value to the output pixel location and stores that value as the new output pixel value;
- **Bi – linear interpolation** – this approach takes the four points in the input image that are surrounding the output pixel location and performs and averaging of their pixel values to generate the output pixel value;
- **Cubic – convolution** – this approach extends upon bi-linear interpolation by using the sixteen surrounding points and performing an averaging technique to calculate the output pixel value.

Orthorectification – overview of procedure

The orthorectification process involves the removal of distortions introduced into imagery as a result of the topographical nature of the ground at the point of capture. Distances on the ground will vary considerably to that measured in the image due to differences in the height of the terrain, and therefore to attempt to retrieve any useful information, these issues must be addressed (Schowengerdt 2007).

The process essentially attempts to rectify the problem of single point perspective introduced through using a camera, whereby all light passes through a single point and is focussed on the lens, and transform the image so that it can be considered that all light falls perpendicularly onto the image i.e. the same as seen in a map. This is accomplished through applying a digital elevation model (DEM) to the image in question to remove the distortions across the image caused by changes in the height of the ground.

IKONOS Geo Ortho Kit 1m Black and White, and 4m multispectral imagery

The newly acquired satellite imagery used within the project was supplied by European Space Imaging, and originates from the IKONOS satellite. The product is supplied under the name *Geo Ortho Kit*, with each multispectral band (red, green, blue, near-infrared) in a separate file, alongside a combined 1m black and white image. The *Pro* version of the product was selected as this offers the best positional quality and accuracy, taking into account the finances available for expenditure on data sources. The data is quoted as having a 4.8m root mean square error in the horizontal (Orthorectified Product Specifications, Geo Ortho Kit, Space Imaging), which was sufficient for the required work to be undertaken.

The Geo Ortho Kit package was selected as this offered the ability to control the ortho-rectification process, without being forced to accept that of the manufacturer. The product contains the Image Geometry Model (IGM) supplied by IKONOS, which details the geometry of the capturing sensor, and can be used to control the ortho-rectification process. The data was supplied in GeoTIFF format already referenced to

UTM Zone 35T for Thrace, Turkey and zone 35S for Naxos, Greece. In addition the data was supplied with the DRA (dynamic range adjust) selected. This option attempts to better spread the available pixel values across the entire grey scale range, giving better definition and detail to the image.

The orthorectification process was carried out on the Geo Ortho Kit imagery within Erdas Imagine 8.7. This software provides the capability to upload the supplied IGM, which contains the "state" of the sensor at the time of image capture. The rational polynomial coefficients (RPC) are supplied in an accompanying file with each image, and are used to describe the relationship between camera and terrain. Within Erdas Imagine, in addition to this file, a minimum / maximum elevation value, or a DEM can be input to improve the final output product accuracy and remove the terrain displacement effects. The DEM's utilised offered a 10 – 20m horizontal accuracy, with a 2.5m – 10m vertical accuracy. Based upon both the financial constraints of the project, and that this limited the ability to perform any ground control survey, therefore ruling out creation of a custom DEM, this was considered sufficient. Resampling was completed as part of the geometric and orthorectification process. The output from this process was an ortho-rectified image with real world coordinates, capable of providing a data source for real measurements.

TARA – acquired historic archived aerial photography

The data provided by TARA, was taken on sorties (AWD 46) by Royal Air Force (RAF) aircraft, referenced specifically to 22nd November 1943. This entire dataset consisted of 97 photos, with Figure.1 and Figure.2 of Appendix A outlining the coverage of the images.

The main processing technique applied to the aerial archive imagery was simply geo-referencing – the process of applying real world coordinates to the aerial photos. Due to the lack of orientation models of the camera at the time of image capture, the geometric distortions introduced by such things as off-nadir (non-vertical) viewing of the camera's focal plane with respect to the ground could not be rectified. Due to this data being historic and the nature under which it would likely have been captured, the access to any ground control survey points even for simple geo-referencing was deemed impossible. Erdas Imagine 8.7 was used to perform the geo-referencing process.

In addition the inability to complete a ground control survey of the two regions to provide ground control points, resulted in raster base maps at 1:50,000 scale (Soviet Military Mapping) of Naxos (supplied by East View Cartographic.com) being utilised to create the ground control points. However, there were two significant issues relating to their selection. Firstly the contrast and clarity of the aerial images was not guaranteed across all of the images, with many suffering from over and under exposure. This made the process of adhering to ground control point selection near impossible, as man-made features became indiscernible from natural features. Secondly the process of selection was elongated due to the use of base mapping, as a map is more abstract than the image to be referenced (Schowengerdt 2007), making the corresponding selection of features very difficult

The procedure utilised during the geo-referencing of the historic air archived data:

1. Coordinating which photos covered which regions within the Soviet Military Mapping 1:50,000 scale;
2. Loading the photo into Erdas Imagine 8.7;
3. Selecting a Geometric 1st order Polynomial Model transformation. The polynomial model forms the relationship between the coordinates in the distorted image, and those in the base mapping (Schowengerdt 2007), used as the reference product in this case.
4. Locating in both the map and photo a point that can be easily viewed, and recording the position in both the image and coordinate reference systems.
5. This process was repeated to detail as many coincident points to introduce redundancy into the transformation
6. Erdas Imagine computes the residual error of matching each point in both data sources, giving an indication to the accuracy achieved. Analysis of the residuals lead to some being removed and redefined, whereas others were completely disregarded. Due to the nature of the imagery and the available data the threshold for removal altered depending upon the time taken to find sufficient ground control points.
7. The bi-linear interpolation technique was selected to resample the imagery.

The imagery was rectified one photo at a time for a number of reasons; for example the clarity and quality of some images was highly questionable and therefore the performance of a block adjustment for all images in a strip would have lead to significant positional errors being introduced. However, even after extensive comparison of the base mapping to each individual image, in some cases only 4 ground control points could be found. The increased number of matching points found accurately between photo and map can decrease errors in the final image to world transformation matrix.

Each of the resampling techniques considered have associated benefits and drawbacks with regard to output image quality, processing requirements and time required to complete (Campbell 2002). For example, the nearest neighbour approach is computationally inexpensive, as no averaging of neighbouring pixels is required, whereas the other two techniques involve averaging. As a result of averaging pixel values found in the original image, are not necessarily kept in the output image resulting in smoothing and loss of original data. However, with specific regard to the aerial archived data, it seemed appropriate to utilise a bi-linear interpolation technique as this compromised between computational intensity, and therefore time consumption, as well as the effect the "smoothing" had on the final output.

Campbell J.B. (2002) *Introduction to Remote Sensing 3rd Edition,* Taylor & Francis

Schowengerdt R.A. (2007) *Remote Sensing Models and Methods for Image Processing 3rd Edition*, Elsevier