ENVIRONMENTAL IMPACT ASSESSMENT FOLLOW-UP OF INTERCHANGES:ON THE EXPLOITATION OF EXISTING PLANS AND MAPS FOR FFLFS-BASED GROUND INDEPENDENT GEOMETRIC CORRECTION OF AERIAL IMAGES

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ABSTRACT

This paper proposes a methodology for the geometric correction of images taken after the construction of an interchange for environmental impact assessment follow-up. The methodology exploits the topographic map produced for the study and the layouts of the study to avoid collection of new ground control information and DEM. The methodology is applied to an interchange in northern Greece.

INTRODUCTION

Environmental Impact Assessment (EIA) is a formal procedure which aims to highlight, quantify and minimize the impact of a project to the natural and the man-made environment before the final decision for the implementation of the project is made. Typical projects with significant environmental effect are motorways, airports, dams etc. Environmental Impact Assessment follow-up (EIA Follow-up) is the procedure to quantify the impact of the project during and after its construction, a procedure which benefits from regular acquisition of aerial images of the area of the project [1, 2, 3]. The iterative collection of images demands repetition of the process of the geometric correction of the images (georeferencing and orthorectification) as well as collection of the necessary ground control information and DEM, making the process time consuming and expensive. Additionally the construction changes severely the topographic details of the area and it is not always easy to identify and collect reliable ground control points (Figure 1).

This paper exploits existing plans and maps used and/or produced during the study of an interchange in order to introduce a ground independent, and therefore fast, geometric correction of aerial images of interchanges. Assuming that the interchange is built according to the study, the georeferencing of the aerial image can be done using the axes and/or the edges of the ramps of the interchange as ground control linear features. The edges are always available on the image, in contrast to points which may or may not be available. In the case that the interchange is not built according to the study, an infrequent but not impossible situation, the georeferencing of the image can be done using the axes/edges of existing roads of the broader area of the interchange, which were not affected by the construction. The 3D coordinates of the ramps are taken from the study of the interchange while the 3D coordinates of existing roads are taken from the topographic map used for the study. The orthorectification of the aerial images can then be done using the DEM which was also used for the study, modified to take into account the elevation of the surface of the ramps provided by the study.

The proposed process is applied to the geometric correction of a real aerial image that illustrates a trumpet interchange between a motorway and a national road. The layouts of the interchange (horizontal alignment and profiles) are used as source of ground control information in order to compute the orientation of the images. The topographic map of scale 1:500 which was used for the design of the layouts is used as source of elevation information in order to orthorectify the images. Results and problems are discussed and issues for further research are presented.

METHODOLOGY

The georeferencing of the aerial images is the computation of the projection transformation between the 3D object space and the 2D image space. The type of the projection transformation is assumed and the computation determines the numerical values of the parameters of the projection. The type of the projection may be either empirical such as the 3D-Direct Linear Transform, or, if known, the physical model of the sensor which acquired the images such as the central projection for aerial images. In order to compute the parameters, both the 3D object coordinates and the 2D image coordinates of some control features need to be known. The features should be easily identifiable on the image and the most common features are the control points. However the available control features are the axes and the edges of the ramps of the interchange and the axes of various rural roads. Thus it is difficult, if not impossible, to clearly identify individual points both on the images and on the plans of the study of the interchange, or on the topographic map of the region. On the other hand Free Form Linear Features (FFLFs) are easily identified, they tend to persist through time and provide a continuous source of control information [4, 5] and are ideal for ground control information. The FFLFs are modeled as a sequences of unevenly distributed nodes linked by straight lines or some higher order function such as the clothoid which is routinely used in motorways. The nodes of a 3D FFLF and its corresponding 2D FFLF are in general different and do not correspond to each other [5].

The FFLFs are matched using a method based in the Iterated Closed Point (ICP) algorithm [4, 5]. The method produces as a by-product a large number of correspondent points which can be used to compute the parameters of the projection with the linear or non-linear Least Square Adjustment (LSA). The method has been applied successfully to the georeferencing of historical images [6] and to the georeferencing and co-registration of optical and SAR images [7] among others.

Given the georeferencing, the image can be orthorectified if a DEM of the region is available. The original topographic map which was produced for the study of the interchange could be used as a DEM. However the map does not include the interchange which was constructed after the map production. Assuming that the interchange was constructed according to the plans of the study, the elevations of the motorway and of the ramps are known from the layouts of the interchange (horizontal alignment and profiles). The axes and the edges of the motorway and of the ramps form convenient breaklines for the new DEM. The foot of the inclined planes at the banks of the ramps and the motorway also form breaklines which encapsulate the affected by the construction area. The affected area on the original topographic map (encapsulated by the breaklines) is cleared of all elevations as they no longer represent the terrain after the construction of the interchange. Then the same area is filled with elevations from the layouts of the interchange. The resulting DEM is used for the orthorectification of the image.

Figure 1: Terrain before (left) and after the construction (right).

APPLICATION

The proposed methodology is applied to a trumpet interchange between the EGNATIA motorway and a national road in Northern Greece near the city of Alexandroupoli. The study of the interchange was done in 1998 and its construction had mostly finished in early 2002. Aerial images of approximate scale 1:15000 were acquired in stereo pairs in 2002 by a Leica RMK aerial camera. The images were scanned from coloured positive film by the Vexcel5000 photogrammetric scanner at resolution 25μm/pixel. The entire interchange is visible in one image (Figure 2). The original topographic map and the horizontal alignment of the Egnatia motorway and the ramps are shown in Figure 3. The profile of the Egnatia motorway at the position of the interchange is shown in Figure 4.

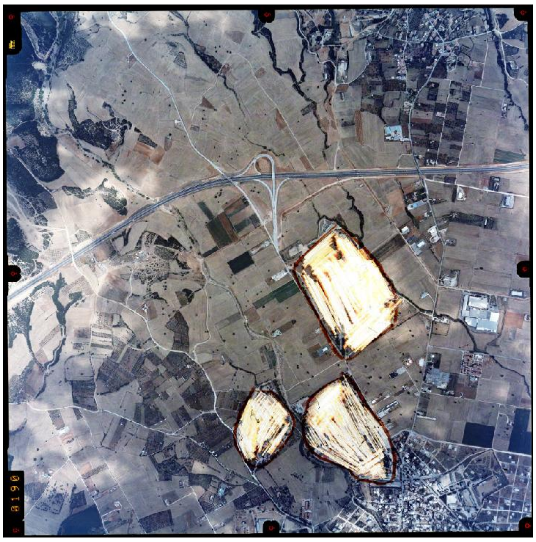

Figure 2: The aerial image of the interchange near Alexandroupoli.

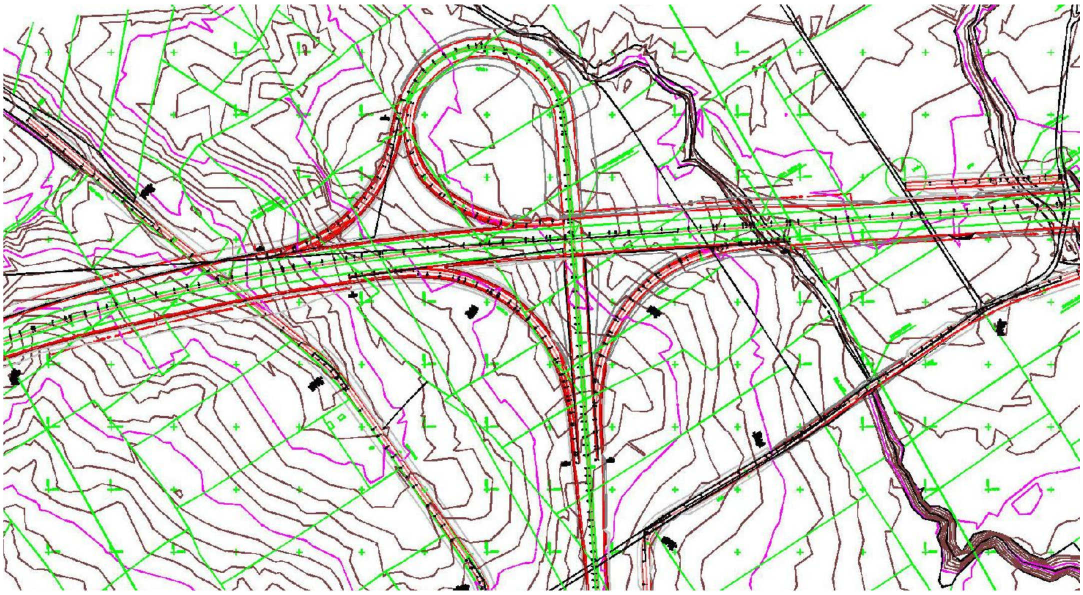

Figure 3: Original topographic map and horizontal alignment of the Egnatia motorway and the ramps of the interchange.

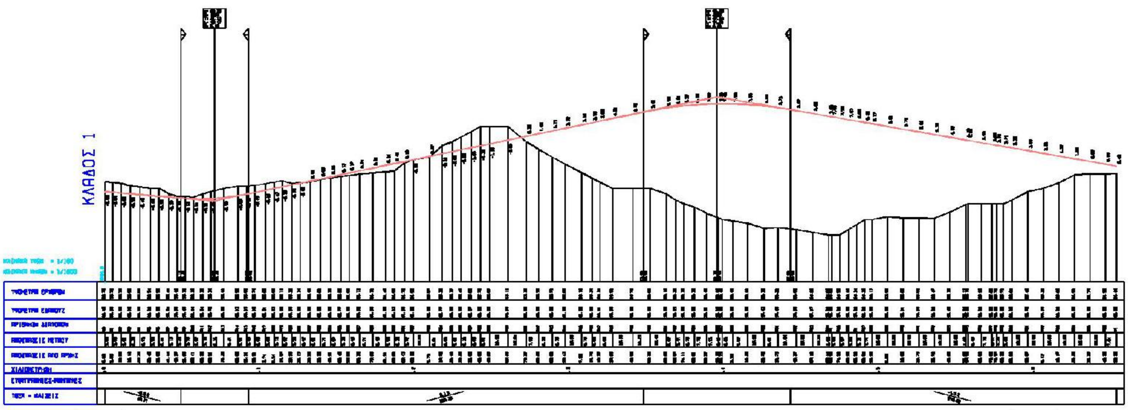

Figure 4: Profile of the Egnatia motorway at the position of the interchange.

The layouts of the interchange (Figures 3, 4) were used as sources of ground control information in order to compute the georeferencing of the image. Specifically the axes of some ramps and a rural road were the ground control linear features (Figure 5). The edges of the ramps and the road were digitised on the image and the correspondent axes were obtained from the edges with skeletonisation techniques. The image axes were then matched to the axes provided by the layouts of the interchange (Figure 5) using matching of a network of FFLFs [4]. The physical model of the aerial images (central projection or collinearity equations) was chosen, and the parameters of the physical model were computed using non-linear LSA:

$$x - x_0 = -c\frac{(X - X_0)r_{11} + (Y - Y_0)r_{12} + (Z - Z_0)r_{13}}{(X - X_0)r_{31} + (Y - Y_0)r_{32} + (Z - Z_0)r_{33}}, \quad y - y_0 = -c\frac{(X - X_0)r_{21} + (Y - Y_0)r_{22} + (Z - Z_0)r_{23}}{(X - X_0)r_{31} + (Y - Y_0)r_{32} + (Z - Z_0)r_{33}} \quad (1)$$

The error of the matching using the physical model was 6.6 pixels or 2.4 m.

Using the computed physical model, the ramps, the motorway and the rural road of the study were projected to the aerial image. Surprisingly it was found that the constructed motorway was displaced by 25.9 m to the North East of the motorway of the study, as it can be seen in the orthoimage in Figure 6. This fact is also the reason that only the axes shown in Figure 5 were used as ground control linear features for the computation of the physical model. Thus in the case that the interchange is not built according to the study, the georeferencing of the image can be done using the axes of existing roads of the broader area of the interchange, which were not affected by the construction.

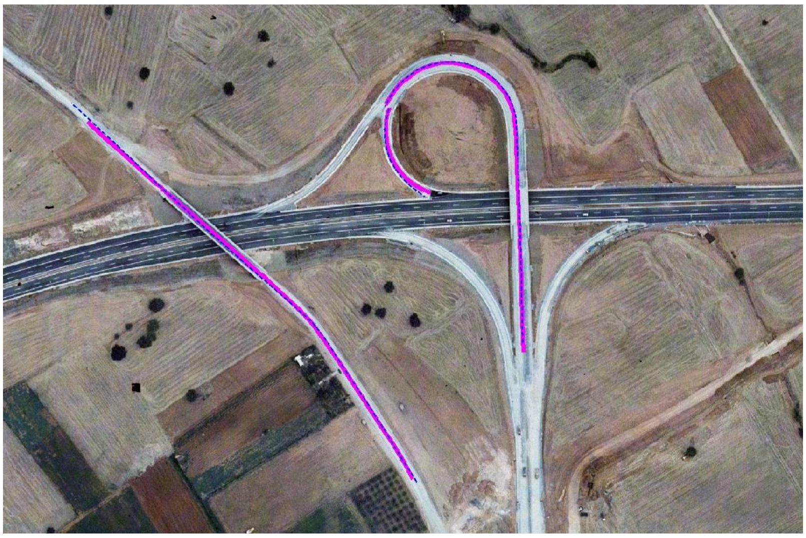

Figure 5: The 2D axes digitised on the image (magenta continuous) matched to the 3D axes obtained by the study (blue dashed).

For the orthorectification of the image, it is apparent that the elevations taken from the study on the surface of the motorway can not be directly used, as the motorway was constructed at a different location. However, for illustration purposes, the rigid vector displacement (dx, dy) of the constructed motorway with respect to the one in the study was computed, using FFLF matching between their axes. The displacement was found dx=15.0 and dy=21.1 m. Then the axis and the edges of the motorway in the study was displaced by (dx, dy), so that the elevations could be used for the orthorectification of the image. The original topographic map of scale 1:500 (Figure 2) minus the area occupied by the constructed ramps, motorway and roads was also used for the orthorectification. The orthorectified image is shown in Figure 6. No attempt was made to displace the ramps which lead to the motorway, as they were much more complicated.

Figure 6: Geometrically corrected image with the ramps and the rural road of the study.

CONCLUSIONS

In this paper, we studied the geometric correction of aerial images for environmental impact assessment follow-up using existing data. It was shown that it is possible to use the topographic maps produced for the study of a project, in order to orthorectify later images of the constructed project. The elevation information of the area occupied by the project is taken from the plans of the study of the project. The use of FFLFs is catalytic because linear features are easily identified, they tend to persist through time and give a continuous source of control information, and because the construction may change the landscape severely, making point identification difficult. An implicit precondition is that the project is constructed as studied. For further research the methodology could be validated by a project constructed as studied. Other projects than interchanges could be tried.

ACKNOWLEDGEMENTS

This research was funded by the research project “State-of-the-art mapping technologies for Public Work Studies and Environmental Impact Assessment Studies” (SUM). For the Greek side SUM project is co-funded by the EU (European Regional Development Fund/ERDF) and the General Secretariat for Research and Technology (GSRT) under the framework of the Operational Programme "Competitiveness and Entrepreneurship", "Greece-Israel Bilateral R&T Cooperation 2013-2015.

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