Georeferencing Aerial Photography: Beginners Approach

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Abstract: Georeferencing aerial photographs has always been a challenge. Computer technology makes it possible to georeference digital aerial photographs without an in-depth understanding of the underlying theory. For students of remote sensing, hands-on manual georeferencing is essential to fully understand the theories and the nature of errors in aerial photography. This paper provides a manual procedure to convert aerial photographs into an orthophoto-like product.

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Introduction

Until recently, aerial photographs have been provided without any locational information. The only way to know the place of a given aerial photo is through the use of its index number. Orthophotography was the only way to obtain aerial photographs that are rectified to a particular map projection such as Universal Transverse Mercator (UTM). Orthophotographs are planimetric by design, in that they represent true measurements within a given scale and standard. Historically, the production of orthophotographs required special equipment not accessible to the public. Today, with the aid of computer technology, digitally georeferenced data can be obtained and developed at the personal-computer level. Locational data can be transformed from scanned U.S. Geological Survey (USGS) maps or by using global positioning systems (GPS). Combined with geographic information systems and remote sensing technology, georeferencing aerial photography is becoming easier (Greve 1996).

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This paper argues that students of remote sensing must know the basics of georeferencing before using available technology. The paper contains an exercise designed to give hands-on experience in georeferencing aerial photography using simple cartographic materials and tools. It is important to note that the final product is not planimetric, because no change will be made to the photograph itself. The procedures used are meant to be only an exercise; the basics behind this are what have been used by most designers' software.

Literature Review

The systematic errors of an aerial photograph are due to five main reasons. These are the failure of the fiducial axes to intersect at the principal point, lens distortion, atmospheric distortion, earth curvature, and shrinkage or expansion of the photographic materials (Moffitt and Mikhail 1980; Wolf 1983). Image displacement that causes the top of high objects to move away from the center of the photo is not an error, but it can cause one if not interpreted properly (Greve 1996). When an attempt is made to georeference an aerial photo, personal errors must be considered. In addition, tools of locational measurement such as GPS, with its own limitations, contribute to many more possible errors (Greve 1996). Statistical procedures are used to analyze the nature of these errors and give a best solution. Techniques such as regression analysis have been used to find the best solution (Slama et al. 1980). Understanding these key procedures requires an understanding of both the nature of aerial photography and statistical analysis techniques. The attempt of this paper is to present a manual georeferencing technique that may be applied to rectify an aerial photograph, as well as to gain a better understanding of the georeferencing process.

General Procedure

An aerial photograph of the University of New Orleans in Louisiana was obtained through the National Aerial Photography Program (NAPP) (Fig. 1). The index number of the photo is NAPP 7508-58, 1-31-94. The original scale of the photo is 1:40,000. At that scale, image displacement can be ignored. To georeference this aerial photograph in the classroom, a 1:24,000 USGS map is used to obtain the locational data (GPS could have been used as well). The first step in the process is to locate three points that can be identified on both the aerial photo and the map. Point one is a bridge over a bayou, point two is a bridge over the same bayou near the lake, and point three is a corner of a traffic island (Fig. 1).

Using interpolation techniques on the USGS map, the UTM coordinates for the three points were calculated. Fig. 2 is an example of the calculation for Point 1. The UTM grid size of the map is 1,000 m on the ground, shown as 4.1 cm on the map. Point 1 is 2.16 and 3.28 cm from easting (E) 782,000 and northing (N) 3,324,000. The coordinates were calculated as follows:

$$\text{Easting} = 782{,}000 + (2.16/4.1) * 1{,}000 = 782{,}526$$

$$\text{Northing} = 3{,}324{,}000 + (3.28/4.1) * 1{,}000 = 3{,}324{,}800$$

Fig. 1. University of New Orleans with three points marked on photo

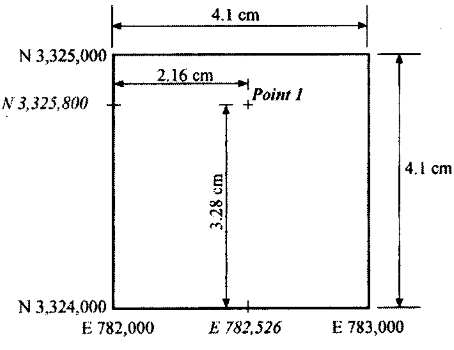

Fig. 2. Interpolating values for point 1

The UTM coordinates for the three points are

1. (3,324,800 N, 782,526 E);
2. (3,325,670 N, 782,191 E); and
3. (3,325,610 N, 783,215 E).

The aim is to establish a grid with tick marks over the aerial photo using these three points. The original USGS map scale is 1:24,000 with UTM grid tick spacing of 1,000 m. The aerial photograph has a larger scale; for that, a 200 m

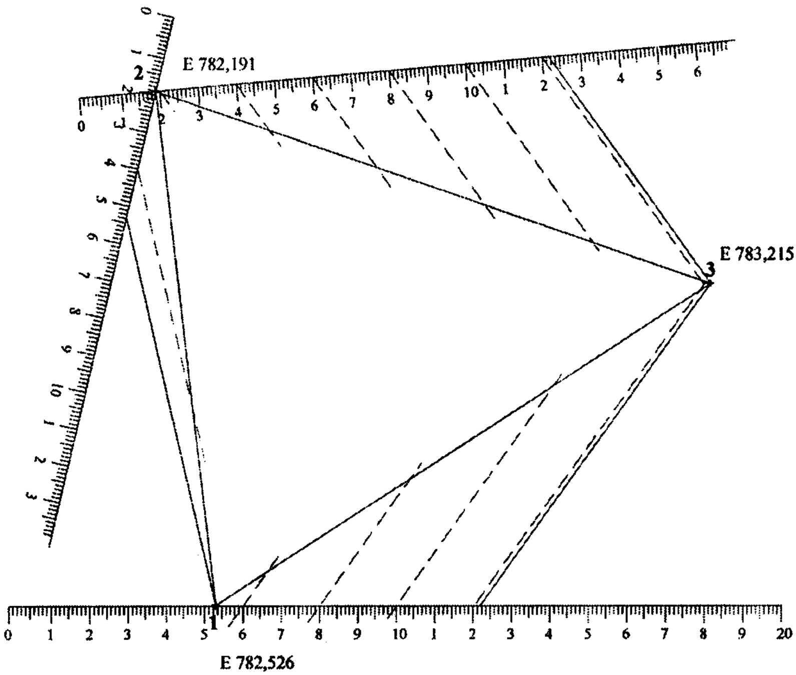

Fig. 3. Establishing 200 m easting intervals on original triangle

grid has been selected. The points were transferred from the photograph onto separate transparencies, and were annotated for their easting and northing values.

The next step is to identify northing and easting grid lines on each of the transparencies. To do this, the interpolation geometric procedure described by Moffitt and Bouchard (1982) and Kavanagh and Bird (1984) has been applied. Using a sliding triangle and a ruler edge, a line can be divided into any number of 200 m UTM intervals. To do this, points 1, 2, and 3 with easting values were transferred onto a transparency (Fig. 3). Using the ruler edge, a temporary line has been stretched to a convenient direction. With the engineering scale, the first number on the ruler (5.26 cm) is selected to match the easting value of Point 1, and the scale is selected so that the easting of Point 3 can be located on the ruler (12.15 cm). On the temporary line, points of integer eastings (6, 8, 10, and 12 cm) with 200 m intervals are identified. To transfer these points to their actual location, a parallel line is extended from Point 1 to Point 3. Parallels to that line, using a Parallelo or two triangles, were used to locate the points on Line 1-3 where the UTMs have 200 m intervals. The same was done on Lines 1-2 and 2-3.

Without the temporary lines, points of equal easting values are connected to form the easting lines (Fig. 4). This was done by connecting points of equal eastings on Lines 1-3, 1-2, and 2-3.

Doing the same with the northings (Figs. 5 and 6), the northing grid has been

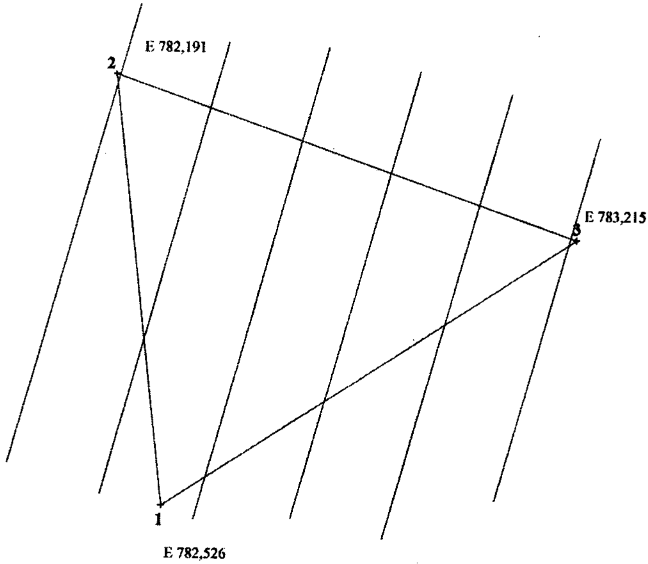

Fig. 4. Triangle with established easting lines

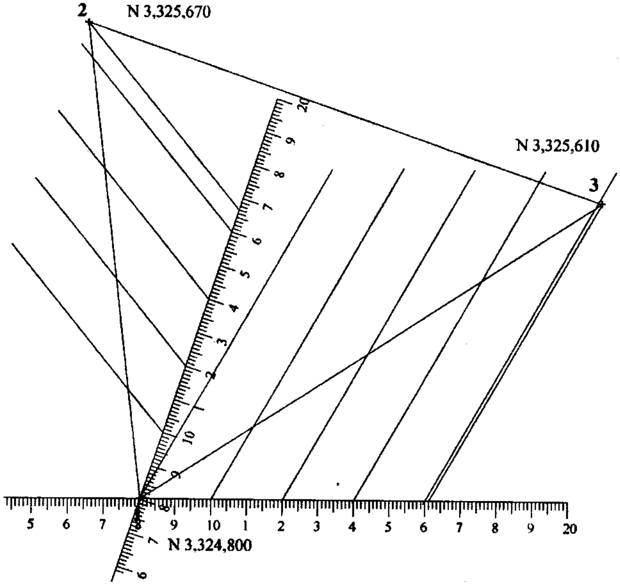

Fig. 5. Establishing 200 m northing intervals on original triangle

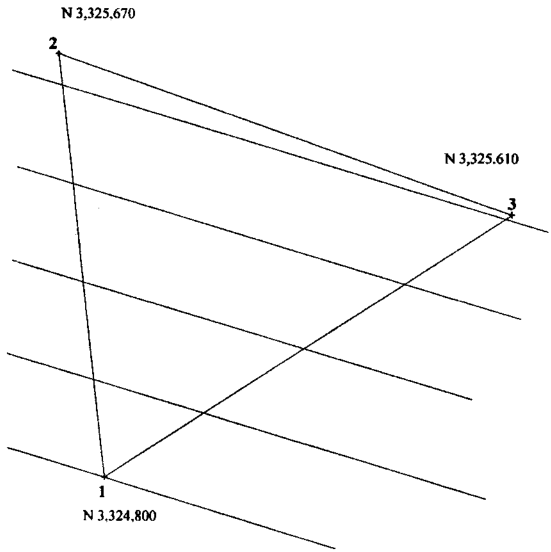

Fig. 6. Triangle with established northing lines

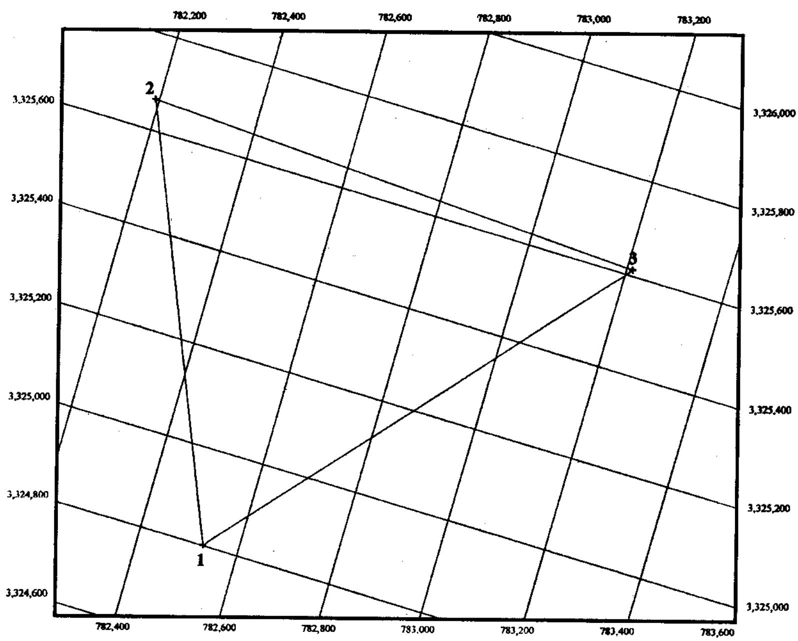

Fig. 7. Combining easting and northing lines to form 200 m grid

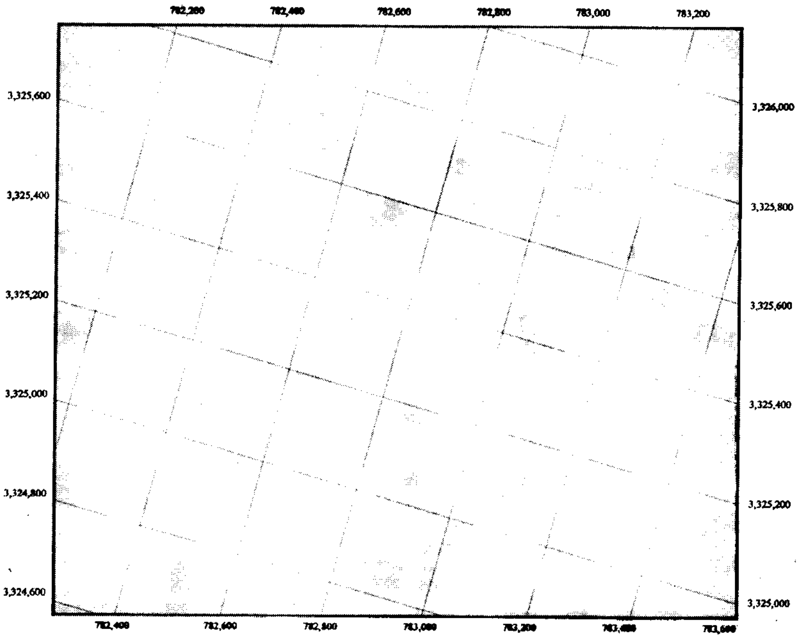

Fig. 8. Aerial photo with 200 m UTM grid

established. It is important to note that no marks were made on Line 2-3, since the difference in northings between them is less than 200 m.

The two grid lines were then overlaid together on a transparency, extended to photo borders, and tick marks were established (Fig. 7). At this point, it is possible to make a judgment on the success of the procedure, since we expect to see a nearly perfect grid.

The grid is then transformed onto the aerial photo. Fig. 8 shows the final result when the grid is transformed to the aerial photograph with tick marks added. The scale can be calculated from the grid and added to the photograph so that it looks like an orthophoto.

Problems and Errors

It is important to recognize that the final product is not planimetrically correct. Measurements are of limited accuracy, since the photo itself was not rectified. All we have done is to add an approximate grid to it.

When several remote sensing students applied the procedure, errors as well as blunders became evident. Some of these were due to mistakes in reading the eastings and northings. Others happened when students did not use the Parallelo properly, causing deformed grids. All solutions that were seriously in error were

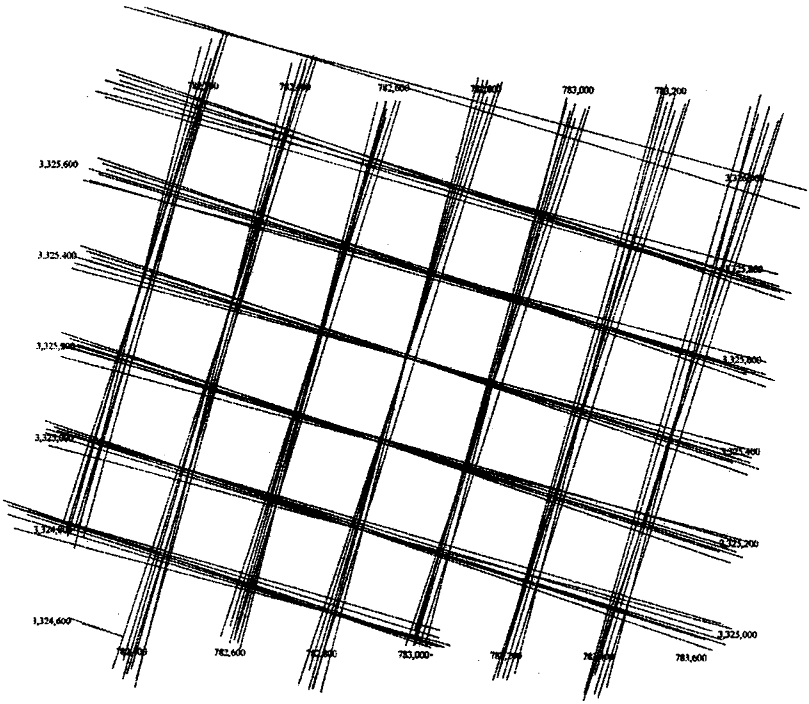

Fig. 9. Grids made by several students of remote sensing

eliminated. The rest were combined in Fig. 9. The different solutions can be related to systematic errors, personal errors, and others that were not accounted for. The combined solutions show that errors are less in the middle and grow larger at the edges. This confirms the fact that systematic errors in aerial photographs are minimal at the center (Wolf 1983).

Conclusion

The location of an aerial photograph is well known during the designing stage of any photography mission. In most flight planes, ground control points are mapped and identified on the ground. Locating an aerial photo through its index number is a very difficult task and requires special expertise that is costly. With present space-age technology, georeferenced digital forms of aerial photography are becoming accessible. Casual users might not need to know all of the details behind the making of these aerial photographs. Applying the method presented in this study helps students understand georeferencing procedures at the classroom level. The procedure may also be of use where computer technology is not available.

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