THE ACCURACY OF MOSAICS*†

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ABSTRACT

A simple method is presented for determining the accuracy of the features on a photo-mosaic as compared to their true geodetic or survey position. This method also indicates the major source of error, causing discrepancies to occur in the distances and directions between points, whether or not this error can be removed, and the accuracy of the mosaic improved.

1. INTRODUCTION

"HOW accurate is this photo-mosaic?" This is a question confronting the user of aerial photo-mosaics as he sets out to determine locations, distances and directions, using the mosaic to aid him in his particular field of endeavor, be he an aerial bombardier determining a target location or a forester locating a particular stand of timber.

The user knows that the mosaic is not a true map and that it is sometimes known as a "map substitute" or "photo-map," containing a wealth of information, some of which cannot be shown on a map. While a map is an *orthographic projection* of a portion of the earth's surface, a photograph, and thus a photo-mosaic, is a *perspective projection* containing certain inherent distortions. Thus arises that question, "How accurate is the mosaic?"

The user of the photo-mosaic needs to know the extent to which it can be used as a map. A question arises concerning the accuracy relationship of the scaled distances and directions between points located on the mosaic and their true geodetic or ground survey counterpart. Fundamentally, this is a problem concerning the error of the relative positioning between features located on the mosaic, and more so to the error in positioning of the single locations.

The study upon which this paper is based was made in order to develop methods for evaluating the positional accuracy of mosaics and for determining the maximum relative positional error of the mosaics. To achieve these results, the effect of errors and distortions upon the relative positional accuracy of the mosaic had to be studied.

2. MAXIMUM RELATIVE POSITIONAL ERROR

The numerical value determined for the maximum relative positional error is the basis for evaluating the mosaic. This value is considered as the maximum relative positional error for "75 per cent of the major cultural and terrain features" appearing on the mosaic as compared to their true ground position in relation to surveyed control.

"Geographic position is defined as the (survey) location of a point on the surface of the earth expressed in terms of latitude and longitude." Positional accuracy is the error in geographic position of single ground points as scaled on a map or mosaic. "The relative positional accuracy of features can be defined as the relation of two or more points falling within the area of a given graphic. As an example, the horizontal positional error of a mosaic is established as not more than 200 feet. This means the measured distance between any two features on the mosaic would be accurate to within 200 feet, or a circle of error of radius 200 feet drawn about either of the features."[1]

The maximum relative positional error

[1] USAF-ACIC Publication RM-401, Target Material Reliability Data (unclassified).

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of a mosaic is determined in the following manner:

a. The maximum plus and minus discrepancies in both latitude and longitude are determined between the scaled position and the true ground position for 75 per cent of the major check points. Linear units of measure are used to facilitate computation.

b. The absolute values of these maximum discrepancies are added (without regard to sign) in each direction and the root mean square sum of these values are considered as the maximum relative positional error of the analyzed mosaic.

3. Methods of Analysis

The first step in conducting the analysis is obtaining the best control and source maps available for the area of coverage of the mosaic. Control is selected for recency, preferred datum and precision, and source maps for desired scale, recency of survey and publication, and accuracy.

Source maps are evaluated against the control for the sake of expediency and the lack of sufficient photo-identifiable control. Check points common to mosaic and source map are then located and the discrepancies determined between the mosaic position and the source map position. The maximum relative positional error of the subject mosaic is then computed by applying the relative positional error of the source map to that of the subject mosaic with the source map.

The analysis procedures followed in this study are based upon these methods. Check points are chosen with respect to elevation, and sufficient points are chosen at common elevations to obtain a positional evaluation for that level. At least three points are selected within the tear lines of separate prints (depending upon the size of the section) in order to determine the plane of that print. Sufficient check points are chosen within each mosaic in order to reach a proper evaluation of that mosaic.

A study of the source map is made to assess the relief in the area of coverage. For a small difference in elevation, the average elevation of the terrain is determined and all check points are chosen at approximately this average elevation. For separate and distinct levels of elevation, an average elevation is determined for each level, and check points are chosen at each of these average elevations. Where there are large differences in elevation (rugged terrain), the area is stratified into elevation zones and sufficient check points are chosen within each zone to estimate the effect of relief displacement.

A study of the positional discrepancies of the check points is then made to determine the types of error which most affect the positioning of the subject mosaic and the amount of discrepancy introduced by this error.

A detailed analysis of a number of mosaics has been made. This study was sufficient to indicate certain trends to the errors in mosaics, but further research is required to achieve quantitative results.

4. Types of Mosaics Studied

The types of photo mosaics analyzed in the course of this study have varied from uncontrolled to highly controlled.

The uncontrolled mosaics were laid using a central position as the basis for geographic positioning, azimuth was determined by holding to the direction between two check points defined by basic control or source maps, and the remaining prints were laid by matching detail to the center photograph. The aerial photographs used were generally considered to be near vertical and were not rectified. In general, the uncontrolled mosaics have been evaluated with larger maximum relative positional errors. Compilation source material in these cases has been of extremely small scale (1:1,000,000) or less accurate, medium scale maps (1:100,000 to 1:250,000.)

The controlled mosaics were laid to a network of control or to a base obtained from source maps. The control network was formed by either plotting the scale positions of identifiable control points or by means of a radial line plot. To obtain accuracy compatible with the denser control, the photographs were usually rectified. Smaller portions of the prints were sometimes used to better fit the control. It is not believed that scale was changed to coincide with differences in elevation. The controlled mosaics have generally been evaluated to smaller maximum relative positional errors; and in most cases, more accurate larger scale maps (1:25,000 to 1:100,000) have been used as source material for these compilations.

5. Sources of Error

It was found that there are four major sources of error causing positional discrepancies in mosaics: relief displacement or the effect of differences in elevation; tilt or the inclination of the film from the vertical; the scale and accuracy of the source material used during compilation; and the methods and techniques of compilation.

Any or all of these major errors may be present in a mosaic, but usually one will be of sufficient magnitude to overshadow the effects of the others. Of these sources of error, only one, elevation, is inherent in the photography; the others are within the ability of the compiler to correct. In many instances, the discrepancies caused by relief displacement can be lessened by increasing the density of the control and by using smaller portions of the photographs during compilation.

In order to study each of these variables, it is necessary to know or assume that the other three are negligible. A detailed compilation history may give sufficient information to simplify the error determination.

a. Elevation:

To study the error caused by differences in elevation, it must first be assumed that the photographs are vertical and that the errors introduced by the source maps and compilation are not large enough to be significant.

Relatively flat terrain will contain no errors due to relief displacement, and the relative positional error should be constant throughout the mosaic.

Many mosaics will contain two distinct levels of elevation distributed over two or three portions of the mosaic. Usually these two levels are located at river valleys or flood plains and the bordering plateau or hill regions. In these cases, the relative positional error of each of the two levels will be approximately the same while that of the entire mosaic will be of a greater magnitude.

When the terrain is of a rugged, mountainous nature, most of the cultural features will be located along the stream valleys and the more level sections. Over the area of a single mosaic, these locations will probably be at approximately the same elevation, and a relative positional error can be computed for that level. Other levels of terrain can be recognized and compared to the positional accuracy of the valley level. The one such mosaic studied was located in an area of poor source material and could not be accurately checked.

Thus it is seen that relief displacement does affect the relative positional accuracy of the mosaic. The magnitude of this effect varies with the type of mosaic (uncontrolled or controlled) and the size of the photo portions used for compilation. Further research is required to determine the relation between relief displacement and relative positional error under the different compilation techniques.

b. Tilt:

The error introduced by tilt and the direction of tilt can be detected by the pattern and magnitude of the positional discrepancies of the scaled check points. The determination of the amplitude of the tilt is beyond the scope of the analysis for relative positional reliability.

The effect of tilt is such as to cause a progressively increasing change to the positional error along the direction of the tilt. This change may occur for both latitude and longitude depending upon the components of the direction of tilt. This systematic variance will normally be restricted to that particular portion of the mosaic, but the error introduced will be transferred to those adjacent portions laid by matching detail to the tilted photos. The effect is most noticeable in uncontrolled mosaics and is reduced in controlled mosaics using smaller segments of the prints.

The errors introduced by tilt can also be recognized when in combination with other sources of error. Where differences in elevation exist and the approximate position of the nadir point can be located, the positional discrepancies can be reduced by the amount of error caused by relief displacement leaving the effects of tilt as residual.

When the major source of error is due to small scale or inaccurate source material or to poor compilation, the effects of tilt may not be evident.

c. Source used during compilation:

The scale and relative positional accuracy of the source maps used as a com-

pilation base may have a measurable effect on the mosaic. This effect will be manifested by a large random distribution of the plus and minus values of the positional discrepancies of the check points. The relative positional accuracy of the mosaic will approximate that expected from the source maps. The pattern of error caused by elevation or tilt may not be evident if they are overshadowed by the larger error due to small scale or poor source material.

d. COMPILATION TECHNIQUES:

The method and techniques of compilation may visibly affect the error of the mosaic provided the errors caused by other sources are negligible. The presence of this source of error may be suspected by gross mis-match of detail, double image, or other evidence of lack of compatibility of the prints. The positional errors of the check points will show the effects of poor "laydown" by a consistent change to scaled values of all check points in the direction of the "laydown" error. The relative positional error of the properly laid portion of the mosaic will be smaller than that of the poorly laid portion.

The size of the portions of prints used may be considered a function of compilation technique and in this case may affect the magnitude of errors caused by other sources.

6. RESULTS OF THE STUDY

a. ELEVATION:

A major source of error for most of the uncontrolled mosaics was due to the effect of relief displacement. In these cases, the distribution of the positional errors approached the pattern peculiar to that caused by differences in elevation.

In controlled mosaics, the error introduced by relief displacement depended upon the amount of relief and upon the density of the control. The size of the photo portions are considered with the density of control. The denser the control, the less was the error due to differences in elevation.

b. TILT:

Since many of the mosaics (both uncontrolled and controlled) were compiled from partially rectified or tilted photographs, the effects of tilt on the positioning was obvious. Some of the uncontrolled mosaics were compiled using unrectified center points of tri-metrogon photography and the direction of tilt of each print could be readily determined.

Most of the photographs used in the controlled mosaics were only partially rectified (restituted), and since there was little effect of relief, the effects of tilt were readily apparent. As expected, the controlled mosaics compiled using rectified photos showed no effects of tilt.

c. SOURCE USED DURING COMPILATION:

In some instances, where small scale or poor source material was used in the compilation of uncontrolled mosaics, the errors were within the limits expected from the error of the source. This error is carried to the mosaic by means of the positional error of the control point selected for geographical positioning, and also in the relative positioning of the points selected for control of azimuth.

Most of the source material used for the controlled mosaics was of more accurate, larger scale maps (1:25,000 to 1:100,000) and did not have a noticeable effect on the positioning of the mosaics.

d. COMPILATION TECHNIQUES:

In some cases, the techniques of compilation or "laydown" contributed to the relative positional error. This error usually occurred in combination with some of the other causes and was more noticeable with the controlled than the uncontrolled mosaics.

7. CONCLUSIONS

The determination of the accuracy of a mosaic is a relatively simple process, as is the determination of that source of error which may have the greatest adverse effect upon the positional reliability. An accurate analysis of this type is predicated upon the availability of adequate source maps or control. (In many instances, these sources may have been available for compilation of the mosaic.)

The procedures outlined are not complicated and can be performed by the mosaic user with little or no additional information.

The knowledge of the accuracy of the mosaic being used adds greatly to the effectiveness and value of having the mosaic, and the knowledge of the errors present will aid in determining whether a recompilation is warranted or justified.