Technical Documentation for CMAP's Historic Aerial Photography Scanning and Georeferencing Project

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Introduction

The project involves scanning of the CMAP's collection of historic aerial photography for 6 counties (Cook, DuPage, Kane, Lake, McHenry and Will) in Northeastern Illinois, and georeferencing them for archival purposes, GIS-friendliness and public access through the CMAP website. Photos of the region were generally taken every five years, beginning in 1970, and printed on large Mylar sheets, which have limited usefulness in the age of GIS and open data. The scanning and georeferencing is an ongoing project, which began in 2013 with the photographs from 1995. This document pertains to the procedures used for that set, and the technical issues encountered.

General procedures

Scanning of Aerial Photos

The aerial photos are scanned using a Vidar HD3630 scanner, version 4.3.1 (36" flatbed with 800 dpi resolution). The Nextimage software package (version 3.1.3) is used to scan the images as TIFFs. The following settings are used in the Nextimage software to scan the aerial photos:

- Resolution: 250 dpi (descreening)
- Image type: Grayscale (8 bit)
- Levels:
    - Contrast: 0
    - Brightness: 0
    - Gamma: 2.0
    - White point: 255
    - Black point: 0
- Sharpen/Smoothen:
    - Intensity: 0
    - Radius: 1.0
    - Threshold: 0
    - Smoothen: 0
- Saved as type: TIF
    - Compression : Uncompressed
    - B & W compression : Uncompressed

Metadata Creation

A Microsoft Access 2007 database is used to store the metadata for the aerial photos. The data stored in the database about each photo includes:

1. Collection (i.e. year photo was taken)

2. Company that produced air photos
3. Township number
4. Range number
5. Photo number (1-9, each corresponding to four specific township section numbers)
6. County name
7. PLS sections included in the photo
8. Township name (in the photo & current name)
9. Date on the photo
10. Filename of scanned TIFF
11. Comments about the condition of the source Mylar
12. Other minute details such as scanning technician and date

The database consists of a data entry form and a metadata table. Data is entered via the data entry form. Only township name in the photo, date on the photo, comments, scanning technician and scan date are entered or modified via the form. Other details were automatically populated and are not editable in the form, but they are editable in the metadata table. Change of filenames, addition/deletion of files and change of PLS sections are done in the metadata table.

Georeferencing of Aerial Photos

The Georeferencing Toolbar in Esri ArcMap version 10.1 is used for georeferencing.

Reference data used:

- major transportation routes (NIPC, 2005)
- township section boundaries for the 7 counties (NIPC, 2005)
- mosaic dataset of 12” aerial photos (USGS, 2005)
- mosaic dataset of 6” aerial photos (NE Illinois County Consortium, 2010)

The aerial photos are georeferenced for geometric rectification of the data using as many Ground Control Points (GCPs) as possible. GCPs are only created using points that the technician is certain were unchanged between the date the photo was taken and the date of the reference data. Clearly visible, well-defined points (e.g. building corners) are greatly preferred over more ambiguous points (e.g. street intersection centers, township corners); natural features are completely avoided. Roads and township boundaries were often used to create a rough “first pass” set of GCPs, which were then deleted as more accurate points were identified and added.

Linear (1^{st} order) polynomial transformation is used as the interpolation method. The higher-order (2^{nd} & 3^{rd}) polynomial transformations are not used as they generally decreased the distortion around the points at the expense of increased distortion away from the points. However, 2^{nd} order polynomial transformations *can* improve accuracy and decrease Root Mean Square Error (RMSE) when the raw scan contains some form of distortion, as long as the GCPs are well distributed in the image.

Comparison of transformations with well-distributed GCPs:

a) 1st order polynomial transformation for image 4109-04. GCPs are well-distributed.

b) 2nd order polynomial transformation slightly improves accuracy due to well-distributed GCPs.

c) 3rd order polynomial transformation increases distortion regardless of GCPs' distribution.

Comparison of transformations with unevenly-distributed GCPs:

a) GCPs not evenly distributed in image 3907-03.

b) 1st order transformation resulted in less distortion of the features.

c) 2nd order transformation resulted in more distortion of features.

Where possible, GCPs are created near an image's origin (center) and eight fiducial points (corners and edge-midpoints). These 9 points are evenly distributed throughout the image, and additional GCPs are created throughout the image. It is important to reduce not only overall RMSE but also RMSE of individual GCPs.

Placing more GCPs around the GCP with lowest RMSE reduces the overall RMSE considerably, but may increase distortion in other areas of the image. (Note also that the GCP with lowest RMSE probably will change while editing the GCPs).

Technical Issues Encountered

Scanning Issues

Scanning problems involved:

- Scratches on the scanner plate. These cannot be avoided and are present in all the images as either white or black vertical lines depending on their presence on scanner glass or scanner platen, respectively. In this set of aerial photos, there is one prominent black line which is approximately one pixel wide, and there are other white lines in the images which are less than one pixel in width approximately. These lines may or may not be visible depending on the background of the image.
- Dust on the scanner plate (could result in thick black lines in the image, which cover the image features). To avoid this, the surface of the scanner, scanner platen and glass, front and back sides of the photo are cleaned using lint-cloth and soft brush.
- Presence of extra white space in the image (e.g. images 3612-07 & 3615-04). The white space is removed by cropping the image using GIMP 2.6. Then, the original file is replaced by the modified file and the modified file is georeferenced.

Georeferencing Issues

There are a variety of geometric errors observed in this set of aerial imagery such as altitude errors, velocity errors, roll, pitch and yaw. (See Figs. 1-3 below for techniques to minimize distortion in georeferenced images.) Due to lack of any ground control data required for interior orientation of images, the georeferencing is done to an accuracy of 15.0 RMSE.

Due to irregular boundaries around townships 3714, 3715, 3613, 3513 & 3512, certain portions could not be covered with a single photograph. To rectify this there are two aerial photos covering the whole area under consideration (labeled "NIBLE" & "SIBLE" on the photographs, and saved with "_N" & "_S" filename suffixes). There are other minor gaps in photographic coverage for which nothing can be done.

Some aerial photos are repeated either to correct drift or image contrast adjustments (3511-08 & 3511-08-1, 3911-01 & 3911-01-1, 3714-08 & 3714-08-1, &, 3512-05 & 3512-05-1).

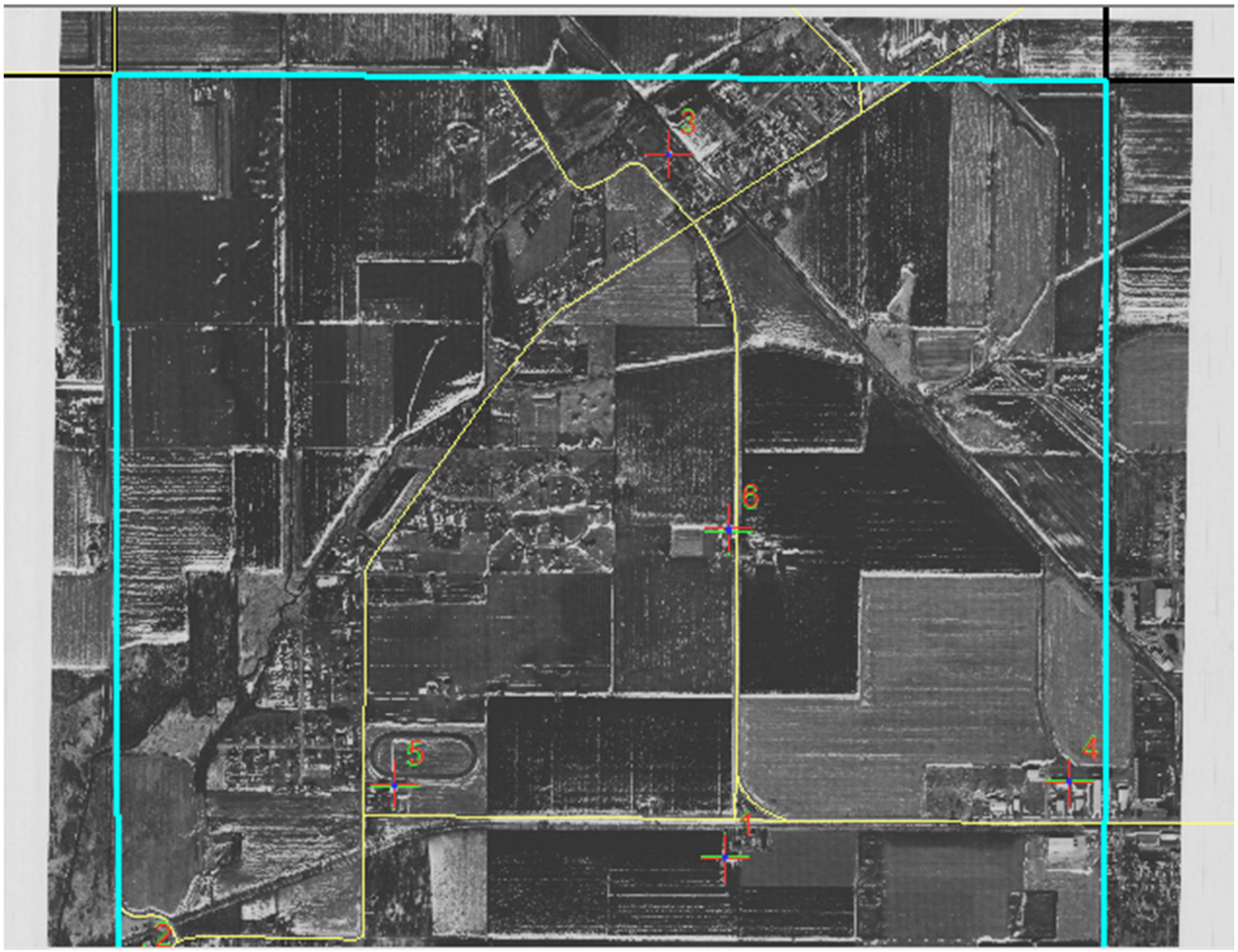

Figure 1. Correction for altitude errors: GCPs are placed randomly avoiding placement along edges.

Figure 2. Correction for roll errors: GCPs are not placed along the edges but rather are placed randomly, mostly in the middle of the image, to reduce the RMSE.

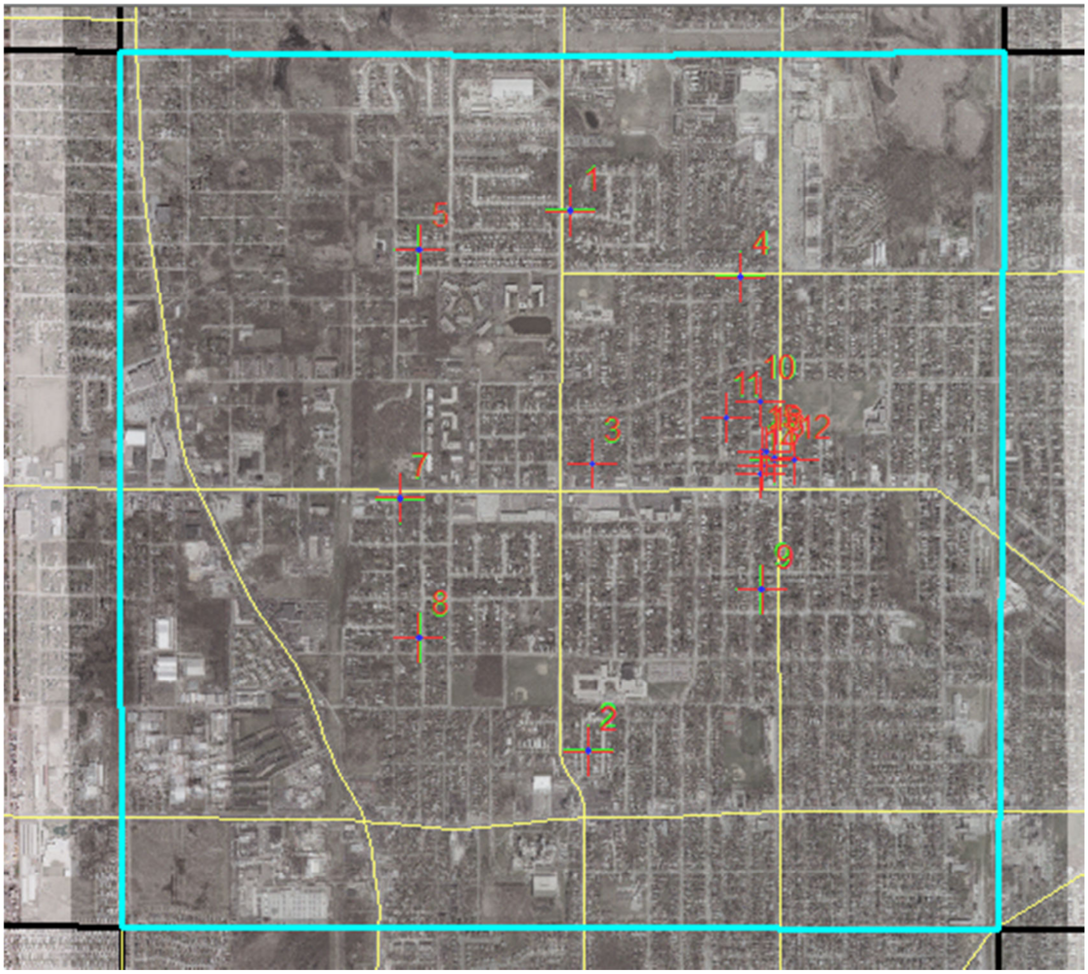

Figure 3. Correction for yaw errors: GCPs are not placed along the edges but are placed in the middle. (GCPs are placed close to one of the GCP with lowest RMSE.)

<u>Miscellaneous Issues</u>

Some files present in the index shapefile are not present in the scanned photos (specifically, 4512-03, 3815-04, & 3914-06). However, these areas are covered by adjacent images.

Apart from these errors, there are other errors like incorrect metadata printed on some aerial photos (e.g. 3609-06 is printed as 3610-06), and scratches/creases on the Mylar sheets which cannot be fixed.

The landscape also poses a challenge to georeferencing. Landscapes vary widely within the region, from barren rural fields to highly populated urban areas. Several rural areas were significantly urbanized between the year of the aerial photo and the years of the reference data available during the georeferencing process (mostly from 2005), so it can be extremely difficult to find reference points. Also, mining areas, lakes, wetlands and rivers occupy a large portion of rural areas where it is difficult to find man-made features with points that are known to be unchanged between 1995 and 2005. Occasionally, man-made features like piers/docks are also used to georeference the areas as harbors, when more-permanent structures are not visible. These issues will be even more problematic when georeferencing photos from before 1995.

Figure 4. Placement of GCPs varies significantly according to local landscapes.

Figure 5. Aerial photos from Rutland Township in 1995 (left) and 2005 (right). There has been a dramatic change of some of the region's rural areas, resulting in a lack of good reference points for georeferencing.

Conclusion

In order to ensure the highest possible quality of georeferencing, 1st order polynomial transformation were used for georeferencing, as the reference data is not accurate and the images are not corrected for interior orientation. However, 2nd order polynomials also were tested and seem to produce good results compared to the 1st order, but with limitations: since the distortion is not evenly distributed in the image, the region beyond the GCPs may have more distortion than 1st order polynomials. The scale distortions and relief displacements increased with use of higher-order polynomial transformations in general. In this set of aerial images, image RMSE varied from 3.0 to 27.0 and most of the images have an RMSE around 15.0 (for 1st order transformation procedures).