Preserving the Past: The Development of a Digital Historical Aerial Photography Archive

The University of Illinois Map and Geography Library maintains a collection of approximately 60,000 individual prints of historical aerial photography that were acquired during the years 1936-1941, for which there are no remaining negatives. Because of high use by library patrons, the collection is deteriorating and a method of preservation is needed. A pilot study was conducted to evaluate the feasibility and appropriateness of digital conversion using high-quality, high-precision scanning. Results indicate that scans produced from the original paper prints exhibit no loss of feature detail, is cost effective on a frame-by-frame basis, and therefore a program of digital conversion should be considered.

INTRODUCTION

Resource-based agencies in Illinois utilize a variety of data sources to derive information concerning the condition and extent of the state's natural and anthropogenic ecosystems, and vertical aerial photography is a singularly unique data source that provides an ungeneralized view of both past and present landscapes. The University of Illinois' Map and Geography Library maintains a repository of more than 160,000 vertical aerial photographs of Illinois counties that were acquired from the late 1930s through 1988, the largest single collection of vertical aerial photography in Illinois. Contained within this collection is statewide historical aerial photography acquired from 1936 to 1941, the most complete U.S. Department of Agriculture coverage known to exist in Illinois. The use of the aerial photography collection at the Map and Geography Library averages 2,000 photos per month, and this usage is resulting in damage and degradation of irreplaceable photography for the period of 1936-1941 for which no known negatives are available. Furthermore, while it is still possible to purchase copies of the post-1950 aerial photography from the U.S. Department of Agriculture, this results in a costly time delay for the user.

THE PROBLEM

There is a significant rate of attrition for the Map and Geography Library's aerial photography collection. The greatest cause of attrition is loss, but deterioration and damage are also significant factors. While the
post-1950 photography is replaced at the rate of one county per year, pre-1950 aerial photography cannot be readily replaced.

Ideally, the original source for prints for pre-1950 aerial photography are silver nitrate film negatives. Approximately 60,000 of the Map and Geography Library’s aerial photographs fit into this category. Unfortunately, original negatives no longer exist for the oldest photography (e.g., 1936-1941), these having been destroyed because, as they became unstable, the heat of hydration caused the nitrate-based film to become gelatinous and combust. Beginning in 1983, the U.S. Navy and the National Archives made a roll-to-roll same-scale conversion of nitrate-based negatives for most states using Kodak 2422 Aerographic Duplicating Film. However, in order to reduce costs of reproduction, aerial photography for some states (including Illinois) were duplicated using a 70mm (2.75 inch) film format. In Illinois, users have complained that reproductions from the 70mm duplicates are poor, and therefore the existing prints for Illinois’ earliest aerial photography are the only remaining high-quality source—and this collection is rapidly deteriorating.

THE SOLUTION

Two strategies are being employed at the University of Illinois to preserve the aerial photography collection: (1) prolong the life of the existing photos through simple preservation techniques, and (2) reproduce the oldest historical aerial photography in a digital format. In order to prolong the life of the existing prints, the Map and Geography Library has experimented with several methods of preservation: (1) encapsulating photography in a mylar envelope, (2) reprography of the original prints, and (3) policies that minimize the handling of the prints but allow accessibility. Aerial photography is no longer permitted to leave the premises, and a modest amount of photointerpretation equipment is available. Photographic reproduction of the pre-1950 aerial photography is currently not an option due to the lack of available storage space. Despite these straightforward measures, deterioration of the oldest aerial photography is continuing.

A second strategy that has been investigated involves high quality/high resolution scanning of the pre-1950 aerial photography, or at least the oldest aerial photography. This form of reproduction accomplishes two objectives: (1) feature detail is faithfully and permanently preserved, and (2) there is no need for a second archive of photographic prints. In addition to preserving aerial photography, the scanned imagery can be edited to improve contrast and repair damage caused by fading and improper processing of the original photos. For example, original prints that have faded because of over fifty years of exposure to natural and artificial light sources can be enhanced by contrast stretching.
A pilot study was conducted by the author using a Crossfield drum scanning system provided by Scantech Color Systems, Inc., Champaign, Illinois. By experimenting with several scanning rates using examples of pre-1950 aerial photography, an optimal sampling rate was determined based upon factors including photo scale, print quality, and paper type. While the optimum sampling rate can vary from photograph to photograph, this rate generally ranges between 31 and 42 micrometers per picture element (pixel). The relationship between these two sampling rates can be more easily understood by relating each to the resulting ground resolution. Using a sample photograph at a nominal scale of 1:20,000 (1 inch = approximately 1,667 feet) that has a contact size of 7 x 9 inches, a sampling rate of 31 micrometers per pixel results in a digital file of approximately 55 megabytes with a ground resolution equivalent to 2.8 feet per pixel. Similarly, a sampling rate of 42 micrometers per pixel produces a digital file of approximately 32 megabytes with a ground resolution equivalent to 3.8 feet per pixel. Careful examination of the original aerial photographs with the scanned imagery revealed that no additional feature detail was added at the higher sampling rate (e.g., 31 micrometers/pixel), and in fact blurring of some surface features was evident. In addition, almost a 60 percent savings in terms of storage space is afforded by the lower sampling rate of 42 micrometers per pixel, and this factor becomes significant when planning for the scanning of county-wide historical aerial photography that can involve over 200 individual photographs.

GEOGRAPHIC INFORMATION SYSTEMS APPLICATIONS

Once historical aerial photographs have been scanned, they can be related to other GIS data sources. This can be demonstrated through a practical application. A few individual frames of historical aerial photography acquired in 1939 for a portion of McHenry County, Illinois, were scanned using the 42 micrometer/pixel sampling rate described above. In addition, the U.S. Geological Survey DOQ (digital orthophoto quadrangle) for McHenry County was acquired. The DOQ is a 1-meter ground resolution image encompassing a geographic area of 3.75 minutes of both latitude and longitude at a source scale of 1:12,000 (1 inch=1,000 feet), and the image data are cast onto the Universal Transverse Mercator projection (NAD 83). DOQs have been mathematically corrected so that distortions from the terrain, camera lens, and from the perspective view have been removed. For McHenry County, the primary source of the DOQ was 1988 NAPP I photography.

Since the DOQs are already geometrically corrected, it is a straightforward mathematical process to transform the scanned historical photographs to conform to the corresponding DOQs. This is facilitated by the
Figure 1. Vertical area photograph situated over McHenry, Illinois, acquired July 16, 1939. After scanning, the image was geometrically corrected to conform to the corresponding digital orthophoto quadrangle.

Figure 2. Digital orthophoto acquired over the McHenry, Illinois area on April 19, 1988.
fact that the sampling rate used for the scanning of the historical aerial
photography results in a ground resolution of approximately 3.8 feet (ap-
approximately 1.16 meters), which is very similar to that of the 1-meter DOQ.
After a sufficient number of corresponding ground control points are
located on both images, the resulting resampled and rescaled historical
imagery can be overlain on the corresponding orthophoto. Change analy-
sis can be employed to delineate the location and extent of landscape
conversions that have occurred between the two acquisition dates.

Figure 1 is a geometrically corrected, historical aerial photograph
that was originally acquired over McHenry, Illinois, on July 16, 1939, at a
scale of approximately 1:11,250 (1 inch=approximately 940 feet). Figure 2
is the corresponding USGS DOQ for the same geographic area acquired
on April 19, 1988. Visual inspection of Figures 1 and 2 shows that a
remarkable amount of change has occurred during the forty-nine year
time interval between the two dates of photography. Most noticeable is
the conversion of rural farmland and wooded land to residential and
commercial land use that has developed south and west of the original
built-up area of McHenry. At the lower right margin of Figure 1 and
adjacent to the Fox River is a large, palustrine deep marsh (PEMf) char-
acterized by two separated areas of open water (dark, nearly black-toned
areas) and interspersed with emergent vegetation (variegated gray-toned
areas). By 1988, the majority of this high-quality marsh had been con-
verted to a diked/impounded riverine open water wetland (R2OWh).
Such conversions of palustrine wetland habitat are common in north-
eastern Illinois, and the use of scanned historical aerial photography in
conjunction with digital orthophotography dramatizes such landscape
changes.

The pilot project also investigated the need to rectify the scanned
historical photography in the same manner as the DOQs in order to re-
move distortions induced by terrain, camera lens, etc. The historical
aerial photography shown in Figure 1 was not rectified and only geo-
metrically corrected to register with the associated DOQ imagery, and
this approach is quite adequate for many applications where precise
ground location is not necessary. For example, the average horizontal
error in registration between Figures 1 and 2 is on the order of a few
meters. Examples of scanned historical photography, along with the cor-
responding USGS DOQ and 1:24,000-scale USGS DEM (digital elevational
model) data, were prepared for two selected geographic areas in St. Clair
and Jo Daviess Counties that express moderate local relief. These data
were provided to a commercial firm (Intera Corporation of Ontario,
Canada) for the purpose of determining the potential cost of producing
historical digital orthophotography. Intera Corporation, which is an ap-
proved vendor for the production of USGS DOQs, provided their ser-
vices at no cost.
Briefly stated, it was ascertained that the production of digital orthophotography developed from historical aerial photography is probably cost prohibitive. Among the factors contributing to this conclusion are the following:

1. Ideally, the rectification procedure requires that camera lens calibration data be provided. Such information includes the camera make/model, lens type/number, focal length, etc. Prior to 1943, U.S. governmental agencies did not formalize camera calibration procedures, and therefore this information is not generally available for the oldest historical aerial photography acquired by the U.S. Department of Agriculture (Brad Johnson, U.S. Geological Survey, personal communication, January 26, 1995). If such data were available for older aerial photography, these would logically reside with the civilian companies that acquired the photography. However, many of these companies either do not exist any longer, have purged these older calibration reports, or have changed addresses and thus are difficult to locate.

2. For both the aerial photography used in Figure 1 as well as the sample data provided to Intera Corporation, nearly fifty years had transpired between the acquisition dates of the scanned historical aerial photography and the DOQs developed from recent NAPP I and NAPP II aerial photography. As a result of the numerous landscape changes that have occurred (e.g., widening of roads, rural to urban/built-up land use conversions, vegetation succession, etc.), collecting a sufficient number of similar ground control points on both dates of imagery for the geometric correction procedure proved to be very time consuming.

3. In one example, a data set incorporating three scanned historical aerial photographs (two end-lapped photographs with one side-lapped photograph), Intera Corporation furnished the rectified historical aerial photography back to the authors for the purpose of ascertaining mosaickability. It was subsequently discovered that remaining distortions were sufficient to preclude the creation of a controlled mosaic, and that only semi-controlled mosaicking was possible. The resolution of the remaining distortions was deemed cost-prohibitive.

CONCLUSION

The results of an intensive pilot project has demonstrated that high-quality precision scanning of historical aerial photography is a viable archiving alternative. At the cost of approximately $30.00 per frame, this is also an affordable alternative for limited geographic areas. However, even the scanning of the pre-1950 collection of statewide aerial
photography encompassing some 60,000 frames is presently cost-prohibitive. It is suggested that cost-sharing initiatives with state and local governmental agencies may be a practical method of distributing the cost. During the period of the pilot project, the University of Illinois Library and one county governmental agency cost-shared to quantize the oldest set of county-wide USDA aerial photography.

Once developed through a joint funding or other funding agreements, the U.S. Geological Survey DOQ product is an inexpensive ($32.00 for each county-based CD ROM) and potentially valuable resource for site-level GIS applications. At the date of this writing, DOQ production for approximately seventeen Illinois counties is either completed or in process. In contrast, the development of digital orthophotography from historical aerial photography appears to be cost-prohibitive at the present time. However, for a large portion of Illinois and on a site-by-site basis, the authors suggest that a simple geometric correction of the scanned photography is sufficient for most GIS applications where the inclusion of historical landscape information may be useful.

Additional information regarding the availability and scanning of historical aerial photography can be acquired by contacting either Donald Luman (217/244-2179) or Christopher Stohr (217/244-2186) at the Illinois State Geological Survey, 615 East Peabody Drive, Champaign, IL 61820. The availability of USGS DOQs as well as all other USGS digital products can be easily reviewed using the Internet USGS World Wide Web home page (http://info.er.usgs.gov/) or by using anonymous ftp (ftp nmdpow9.er.usgs.gov).