Generating tile-based datasets from old aerial photo data

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Abstract

The GSI has archives of aerial photos taken from the pre-war era to the present which are available to the public. Regarding old photos that were taken up to 1974, individual photos cannot be viewed by superimposing them on maps, so it has been difficult to specify such things as locations of photographed objects.

Therefore, utilizing recent advanced image processing techniques, a method has been examined for joining these photos in a simple and easy manner over a wide area and convert them into tile-based dataset so that they can be superimposed on GSI maps.

Furthermore, using this method, aerial photos that were taken by the US Army after the war (hereafter, "US Army photos") of urban areas (mostly urban cores) designated by the government were converted into tiles. This enabled comparisons to be made with photos taken from 1974 on that were already publicly available on the GSI Maps (<http://maps.gsi.go.jp/>), which are Web-based maps provided by GSI on the Internet, and it was apparently possible to see changes in land use in a time series.

In the future, efforts will be made to convert aerial photos taken during the time of the Japanese Imperial Land Survey into tiles using this method, and expand tile-based datasets of past aerial photographs.

1. Introduction

As of this writing (8 September 2015), the GSI houses roughly 1.34 million aerial photographs taken from the pre-war era up to the present time and makes them available to the public. Many of these photographs have been converted into tiles, especially those taken by the GSI from 1974 to 1990, and from 2007 to date. This has made it easy for anyone to view a wide area seamlessly on the GSI Maps. However, older aerial photos have not been converted into tiles, the only way they could be viewed was by confirming the position and orientation of each individual photo.

At the same time, as photographic processing techniques have come into general use due to the popularization of panorama photography, UAV, etc., image processing and orthographical projection can now be done more easily and over a wider area. Therefore, in FY 2014, old aerial photographs that had not been converted into tiles were geometrically converted using these image processing and orthographical projection techniques so that they could be overlain on maps, and a method was examined for converting this data into tiles to view on the GSI Maps.

Furthermore, using this method US Army photos from 1945 to 1950 were converted into tiles, and in March 2015 the tiled data of urban areas designated by the government at the time were publicly released on the GSI Maps. Figure 1 shows publicly released map areas.

Figure 2 shows photograph taken of the Kasumigaseki area of Tokyo. It is a composite mosaic of a photo that was taken on 29 March 1948 of the governmental offices area of Kasumigaseki (Course No. M871), and a photo of the Imperial Palace in the upper section that was taken on 24 July 1947 (Course No. M859).

Using this method, it was possible to convert many US Army photos into tiles in a wide area. However, because those photos were taken a long time ago, it became apparent that there were numerous issues to be resolved, such as deterioration of film and photographic

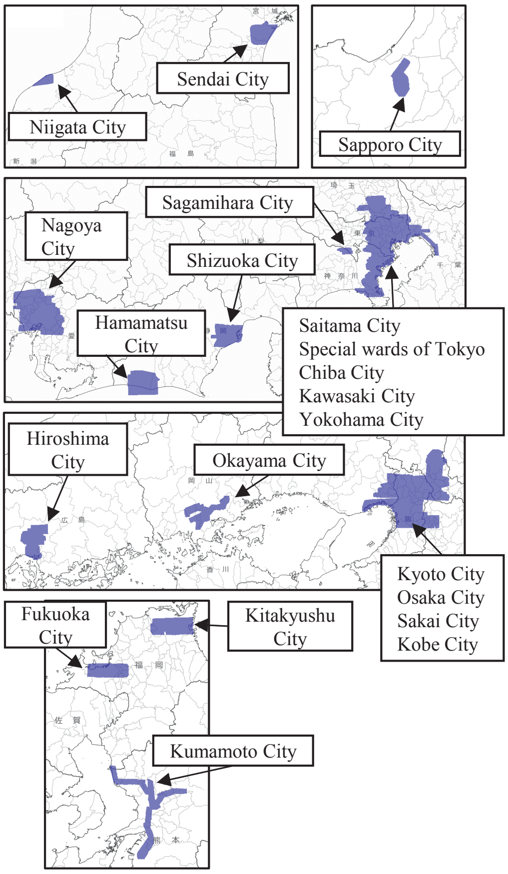

Fig. 1 Publicly released map areas (blue sections)

Fig. 2 Area around Kasumigaseki

procedures which meant that trial-and-error had to be used to convert some of the photos into tiles. The following is a description of the methods that were examined and issues that occurred in this study.

2. Orthographic projection

When doing the geometric conversions so that data of aerial photographic images could be overlain on maps, the work that required the most effort was orientation work for determining corresponding points between pixels of aerial photo image data and map locations. Because this work fundamentally had to be done by hand, it was important to shorten this work to make tile conversion as efficient and effective as possible.

When orienting overlapping aerial photo image data one photo at a time, there was clearly much redundant work involved, and if there was a lot of undulation, it would require numerous reference points to indicate the same point, making it an extremely expensive undertaking.

Therefore, it was decided to reduce distortions caused by undulation and reduce the number of final orientation points by creating ortho-mosaic images of wide areas using bundle block adjustment.

2.1 Bundle block adjustment software

Although there are many types of bundle block adjustment software, it was decided to use the “Pix4d mapper” (hereafter, “pix4d”) made by the Pix4d Company of Switzerland because it was used to create ortho-mosaic images of aerial photographs that were taken of Nishinoshima Island in March 2014 using UAV.

Pix4d is an ortho-mosaic software with powerful image matching functions, which requires only a few settings and steps to create an ortho-image easily from multiple aerial photos. The objective ortho-mosaic image can be obtained in just 3 steps: (1) internal and external orientation, (2) creation of a set of 3-dimensional points, and (3) creation of ortho-mosaic and DSM images.

In order to start-up pix4d and execute the first step (1) of internal and external orientation, it is necessary to have photo data and information about the locations (longitude, latitude, altitude of shooting point), film size, focal distance, and other information. This information is converted into the necessary written CSV format from the records stored by GSI. Once the internal and external orientation is completed, it becomes possible to obtain estimated locations from which each photo was taken and rotation (κ, φ, ω), which can be confirmed visually on the GUI (Fig. 3).

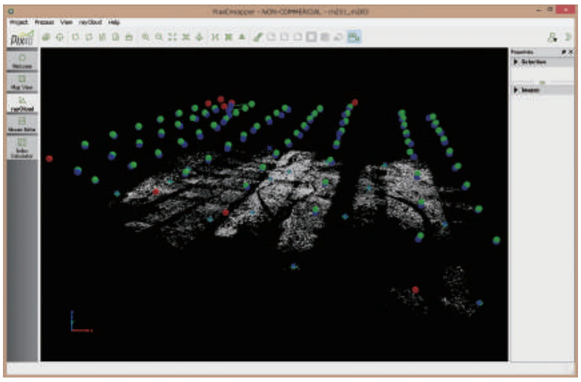

Fig. 3 Display of results of internal and external orientation

The green points are the locations of the initial shooting points of each photograph, the blue points are the locations of estimated shooting points, and the red points are shooting points of photos that could not be used.

If there are no problems with these results, then we can proceed to step (2), creating a set of 3-dimensional points. This creates a 3D model that is necessary for orthographic projection (Fig. 4).

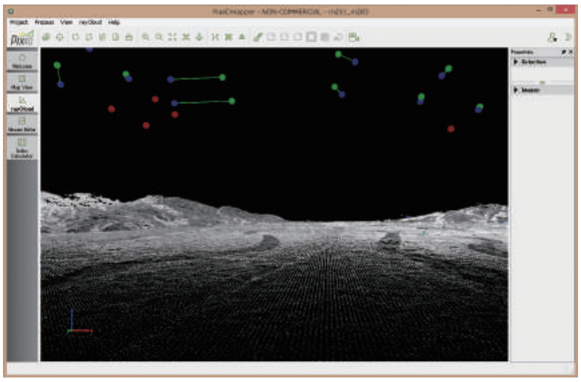

Fig. 4 Display of a 3D model

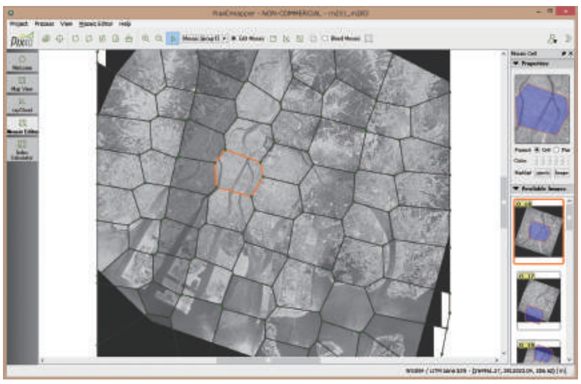

Fig. 5 Display of ortho-mosaic images

If there are no problems with the 3D model, then we proceed to step (3), creation of ortho-mosaic and DSM images. This step will enable us to obtain an ortho-mosaic image (Fig. 5).

2.2 Issues with orthographic projection

2.2.1 Automatic acquisition of tie points and pass points

Pix4d uses image matching techniques to enable automatic acquisition of tie points and pass points required for bundle block adjustment. However, sometimes cannot be done due to such factors as clouds, poor image quality, etc., and areas appear where orthographic projection cannot be done (Figs. 6, 7).

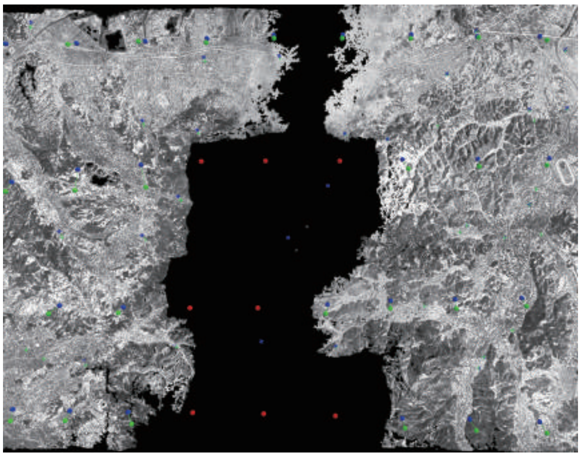

Fig. 6 Example of an area where orthographic projection cannot be done

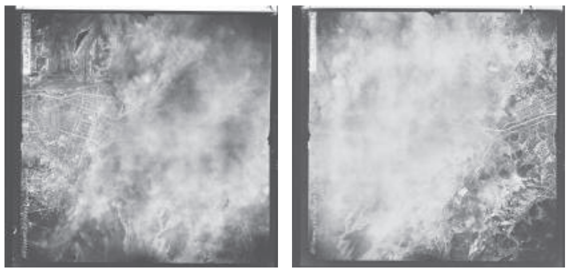

Fig. 7 Examples of photos showing clouds that caused images to be unmatched or mismatched

There are a few cases where image matching is done by adding tie points manually.

2.2.2 Effect of flying conditions on aerial photographs

The US Army photos were not always taken under stable flying conditions and at a fixed altitude, and photos could not always be taken perpendicular to the land surface. In addition, initial parameters that are entered into bundle block adjustment are based on such things as approximate shooting locations which were estimated from maps and flight plan information, rather than actual shooting positions, so there are many cases where calculations have been unsuccessful under such conditions. Figure 8 shows an unsuccessful result where photos could not be melded together. We can probably conclude that the photos were not taken perpendicular to the ground surface.

In cases where there is a single pass point on the photographic course, there is no overlap between pass points, and we can see that the results of bundle block adjustment are not consistent.

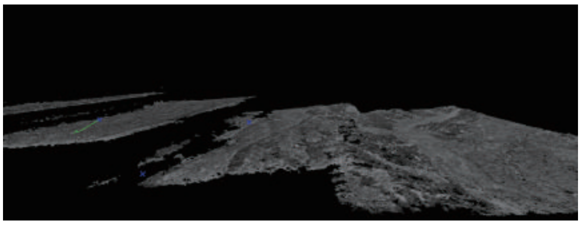

Fig. 8 Example of an unsuccessful result

2.2.3 Artifacts

When the condition of a photo is bad due to, for example, writing on the image, and pixels that have no

Fig. 9 Examples of artifacts

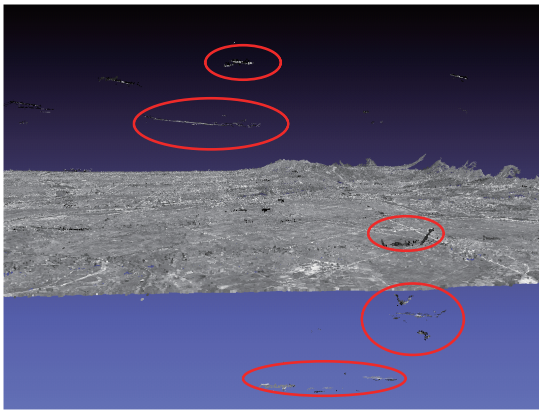

Fig. 10 Example of point sets that caused artifacts

relation to one another are matched up, then the image in that section may have become extremely distorted. This type of section is called an “artifact” (Fig. 9).

Such mistakes in pixel matching are expressed as point sets in unnatural locations in the 3D point set data (Fig. 10).

Therefore, 3D data editing software was used to remove problematic point sets and once again conduct mosaic conversion processing to control the generation of artifacts.

3. Panorama method

When orthographic projection cannot be done due to various factors, then panorama processing was done in which overlapping sections of multiple photographs were joined by automatic image matching, and then attempts were made to create wide area mosaic images. Panorama processing technology has become common due to widespread use in digital cameras, smartphones, and other devices, and there are many types of software in existence. In this work, we used “Image Composite Editor” which is a free software provided by Microsoft Corporation. Using this software, reference points

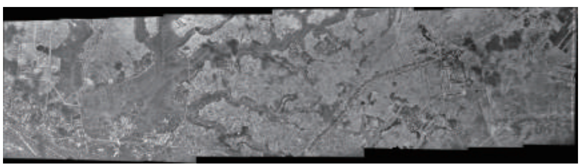

Fig. 11 Example of panorama processing of 8 photographs (vicinity of Funabashi City)

were set for each individual photographic image which eliminated the need to do geometric conversion and could thus save our work. However, flat land areas were selected for this process to avoid local deviations of photo images due to undulation. Then reference points were set in the geometric conversion of the post-processing and combined with absolute positions (Fig. 11).

4. US Army photos that were used in this study

This study used 400dpi resolution JPEG images rather than the 1200dpi TIFF images of our surveying results. This was because 400dpi was a resolution at which several hundred photo images could be compiled and orthographically projected within a few hours. In the case of 1200dpi images, it would take more than one day to process 10 images, even for just orthogonal processing. Furthermore, the size of mosaic images created therefrom would have encompassed hundreds of thousands of pixels, and it would have been difficult to do the post-processing such as geometric conversions, tile conversions, and so on with our workstations, software, etc.

The scale of the US Army photos that were used here basically ranged from ca. 1/10,000 to 1/15,000, and after the processing of the 400dpi photo images, the resolution was about 70-100 cm per pixel. The maximum resolution that can be displayed on GSI maps (zoom level 18) is about 50 cm per pixel, at around a latitude of 35°. Therefore, the tile images that were created here from US Army photos can be said to correspond to a zoom level of 17.

If 1200dpi photo images had been used, then it would have certainly been possible to confirm distinctive planimetric features (Fig. 12). However, because consideration was also given to using GSI maps to look down on a wide area to understand the shapes and positions of planimetric features, and making more detailed checks with crude photographs, it was decided to use, given the current state of productivity, 400dpi JPEG images.

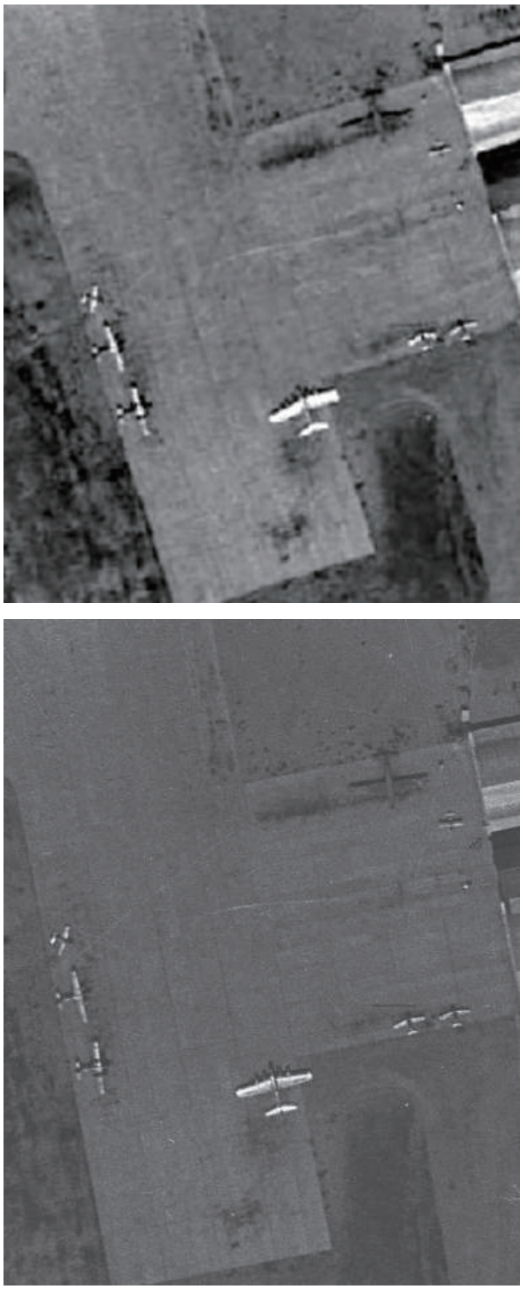

Fig. 12 Differences: 400 dpi (top), and 1200dpi (bottom)

Although the 1200dpi image is more distinctive, in both images the engines of aircraft on a tarmac can be confirmed.

The years of the photos that were used in this study were from 1945 to 1950, and in cases where there were images of the same location for multiple years, the oldest photo was usually selected.

Although the US Army continued to take photographs after 1950, the GSI began to take aerial photographs of the entire country in the 1960s. Therefore, in order to increase the value as an archive for comparing changes in land use, as a rule photos taken in 1951 or later were not used so that there would be no closeness in years.

5. Geometric conversion

Orthographic projection eliminated local deviations due to undulation, and mosaic images could be obtained with relatively good precision, but there were many cases of divergence from the absolute position. Therefore, GIS software was used to geometrically convert images so that roads, etc., on current GSI maps would match up with reference locations.

In many cases, if 20 or so reference points were set, then geometric conversion by bicubic interpolation (which requires at least 10 reference points) could match map positions with satisfactory accuracy.

However, in cases where there was more deviation in mosaic images due to photographic conditions, or mosaic images were created by panorama conversion, more reference points were set, and geometric conversion was rectified by spline interpolation. When spline interpolation was done, there was fundamentally no error in the reference points, but there were many cases where there was great distortion generated by areas surrounding reference points (extrapolated areas). Therefore, such outer areas were removed from the post-processing.

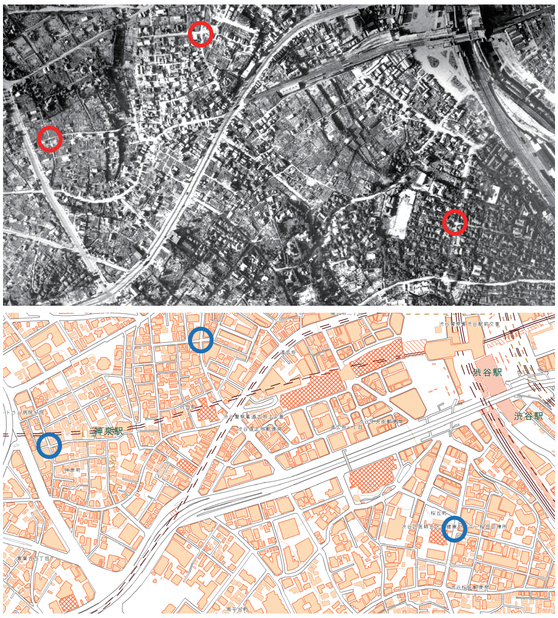

Fig. 13 Example of setting reference points (circles represent corresponding reference points)
(Vicinity of Dogenzaka, near Shibuya Station)
US Army photo (top)
GSI map (bottom)

5.1 Selection of reference points

Over the years, many changes have occurred between the recent GSI maps and the US Army photos, and it is difficult to find planimetric features that are common to both. Basically, road intersections are often used as reference points, but large error can occur if corresponding points cannot be accurately determined due to subsequent road widening, etc. Therefore, it was decided to set reference points in places where there had been no major changes in the old roads (Fig. 13).

Fig. 14 Mouth of old Edo River and vicinity
US Army mosaic image (top)
1:25,000 scale topographic map, surveyed in 1945 (center)
GSI map (standard map) (bottom)

However, for cases where large-scale suburbs had formed, it was not possible to obtain reference points over a wide area. For example, large-scale land reclamation had been undertaken near the mouth of the Edo River, so recent maps could not be used. Therefore, old maps were used to estimate reference points so that there would be no significant deviations (Fig. 14).

6. Removal of edges

Major planimetric features were avoided so that adjacent mosaic images would appear to be merged more cleanly, and image editing software was used to remove edges manually. Basically, in order to avoid a sense of incongruity, the boundaries that were selected for removed edges were such features as ridges in fields and paddies, rivers, forested areas, and areas along roadways.

The removed sections were subjected to transparency processing, then during tile merging of the post-processing, efforts were made not to overlay mosaic images of adjacent photographed areas (Fig. 15).

Fig. 15 Hiyoshi Station area of Yokohama
Image after cropping edges (left)
Merged image (right)

7. Tile conversion

For tile conversion, we used an open source GIS processing library called GDAL. First, the mosaic images were converted into the Web Mercator projection system (EPSG:3857). Then, 256×256 pixel PNG format tile images were created. PNG rather than JPEG images were used in order to save non-photographed areas as transparent areas. After that, we used our own program to merge tiles at the same position with each other to complete the tile conversion of US Army images (Fig. 16).

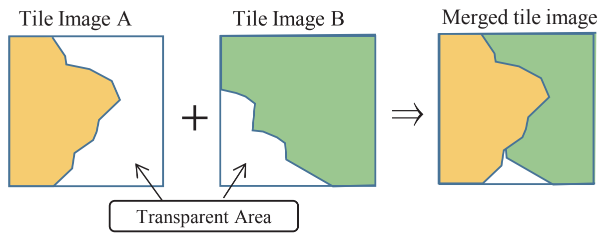

Fig. 16 Merging of tile images

8. Topic for future examination

In this study, 400dpi JPEG data was used to convert areas around government-designated cities (mainly city centers) into tiles in about 9 months. In the future, we will investigate methods for efficiently processing higher resolution data of 1200dpi and above.

However, even with the current computer specs, it is still difficult to do such processing work as orthographic projection unmodified image data of 1200dpi and above, geometric conversion, and so on. Therefore, if we divert the parameters required for orthographic projection obtained at 400dpi and geometric parameters (displacement of each pixel) and apply them to 1200dpi or greater data, then we may be able to reduce the amount of labor needed for orthographic projection and geometric conversion. However, because no such processing programs are available at the current time, we will have to consider creating our own program.

9. Concluding remarks

By creating wide area mosaics using powerful photographic image processing software such as pix4d and panorama conversion software, we were able to efficiently overlay positions on maps. We were also able to easily make tile conversions using open source tools such as GDAL, and there was almost no need to create our own processing programs. Furthermore, we were able to use recent high-spec workstations to process data of image sizes exceeding tens of thousands of pixels with these powerful tools.

However, it became clear that there are still numerous issues to be resolved. For example, due to problems peculiar to US Army photographs such as poor image quality and unstable photographic conditions, mosaic images could not be obtained, and we sometimes had to start over by changing conditions for recalculation, and there were many instances where we could not even use panorama conversion and had to rectify photographs one at a time by hand for tile conversion.

In future studies, we will investigate ways of resolving these issues and efficiently processing 1200dpi images. We also plan to use methods examined in this study to make tile conversions of aerial photos taken by the Japanese Imperial Land Survey in order to improve tile data of old aerial photographs.

References

Japan Society of Photogrammetry and Remote Sensing (2012): Disaster records obtained from aerial photos, Kajima Institute Publishing Co., Ltd., 288-290. (in Japanese)