# DISCUSSION ON THE GENERATION METHOD OF SIMPLIFIED TRUE ORTHO AT THE URBAN AREA USING THE AREA SENSOR TYPE DIGITAL AERIAL CAMERA "DMC"

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**ABSTRACT:**

In this study, We applied the true orthophoto obtained by combining the aerial photograph having high overlap ratio taken by area sensor type digital aerial camera "DMC" with the generation method effectively using the vector data to the fundamental data used by the administration to get rid of the narrow road of the width of 4 m or less at the urban area. We are planning to utilize this method for the business to confirm the application for construction. We discussed the simplified generation method of true orthophoto availing this opportunity as an example.

## 1. INTRODUCTION

Since the digital photogrammetry system has been disseminated, the digital orthophoto which is corrected of the distortion of aerial photograph resulting from undulations of ground has been widely used for the applications such as backdrop image of GIS as the products that are obtained easily at lower cost comparing with vector data. On the other hand, the true orthophoto which can correct not only the undulations of ground but also detailed distortion of buildings, etc. is not much used for the applications as it is rather costly and requires extremely detailed DSM. As a result, the true orthophoto is positioned by very special and costly product and is used in many cases for the state-of-the-art projects.
In this study, we attempted to generate true orthophoto at relatively low cost using highly overlapped photographing by aerial digital camera and simplified generation method with the relative detail corresponding to the use purpose and apply it to the project for the construction of basic data of administration in an aim to eliminate the narrow roads in the urban area.

## 2. PROBLEM OF NARROW ROADS IN THE WARD AREAS OF TOKYO

The existence of narrow roads with the width of 4 m or less creates obstacles for the smooth traffic and formation of good urban environment, disturbs the smooth evacuation and rescue activities at the time of disaster such as fire or earthquake, and brings about threats to the livelihood of citizens. Also, the buildings are crowded in most areas of narrow road, creating a big problem for the disaster prevention at urban areas.
These narrow roads at the urban area should have been weeded out at the time of re-construction of building by the premise set back system specified by the Construction Standard Act enforced in 1950, and after 50 years from such legislation, it has been considered that the majority of narrow roads had already been removed. However, many narrow roads are still existing in the ward area of Tokyo. At the periphery of Honcho of Shibuya-ku, for example, the ratio of narrow roads against total length of road is as high as more than 50%.
The following reasons can be pointed out for the reason why the present situation has been created.

- These roads are private road and it is hard to identify these roads because access to it is difficult.
- It is difficult to confirm the center line of these narrow roads, and the position of set back cannot be determined at the time of reconstruction control of building.
- Although set back is made at the time of reconstruction of building, the space generated by it is not secured as the road space (construction of L-shaped side groove, etc.).

Typical narrow roads around Shibuya-ward are shown in figure 1. Image on the left shows one of private narrow road, image on the right shows condition of shadow at narrow road.


Figure 1. Condition of typical narrow road

As a solution for this problem, it has been desired to grasp the actual state of narrow roads and generate the maps with high positional accuracy to improve the efficiency in the construction control and road administration. Some administrative agencies are considering preparing the highly detailed and accurate orthophoto as a part of fundamental data. Figure 2 shows the image of utilization of basic data to the construction control at the area of narrow road.

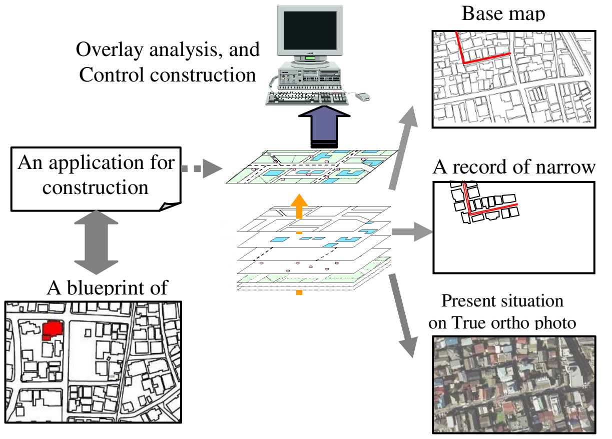


Figure 2: Image of using fundamental data for the construction control at the narrow road areas

The following maters can be pointed out as the technical problem in this case.

1. There are quite many occlusions of buildings as there are many tall buildings.
2. It's necessary to prepare 3 dimensional high precision building edge line for generating true orthophoto.
3. Shaded portion is larger at the building crowded area, and therefore, it is difficult to take a clear aerial photography.
4. It is difficult to spend high cost comparing with the cost necessary for the generation of ordinary orthophoto.

Based on the recognition of these problems, we discussed the generation method of true orthophoto applying and taking advantage of merits of area sensor type digital aerial camera DMC.

## 3. DISUCUSSION OF METHOD

### 3.1 General description of area sensor type digital aerial camera DMC

DMC is an area sensor type aerial camera using CCD array (Figure 3). The camera body unit is composed of 8 camera heads, namely 4 high resolution panchromatic cameras using CCD array of 7K x 4K and 4 multi spectra cameras using CCD array of 3K x 2K (Figure 4). The multi spectra cameras collect data from red, green, blue and near infrared bands. 4 high resolution panchromatic images are mosaiced by post processing. Also, RGB or near infrared color image is synthesized by pan-sharpen processing. Main capacities are shown in Table 1.

Figure 3. Appearance of DMC

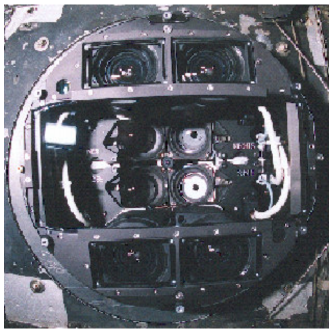

Figure 4. 8 camera heads

| | |
|---|---|
| Structure | High resolution panchromatic or multi spectra of 14K x 8K |
| Shooting angle | 74 (perpendicular to flying direction) x 44 (flying direction) |
| PAN:<br>Resolution, optical system | 13,824 x 7,680 pixels (final output image)<br>4 pieces, f = 120 mm / 1:40 |
| MS:<br>Channel, raw resolution, resolution of pan-sharp, optical system | RGB / NIR<br>3,000 x 2,000 pixels<br>13,824 x 7680 pixels (final output image)<br>4 pieces; f = 25 mm / 1:4.0 |
| Shutter, Iris | Variable 1/50 – 1/300, f/4 – f/22 |
| MDR<br>(Mission data recorder) | 840 GB (about 2,000 or more images) |
| Shortest shutter interval | 2 seconds / image |
| Radiometry | 12bits |
| Position and Orientation recorder | POS/AV 510 |

Table 1. Details of main capacity of DMC

### 3.2 Proposal method

Using DMC system, we propose the method of generating true orthophoto for suitable application purpose and cost effectiveness under conditions listed below.

- Taking high-overlapped photography without extra cost.
- Acquisition cost effective 3 dimensional vector data

- Apply high density color depth

Flowchart of proposal method is shown in figure 5.

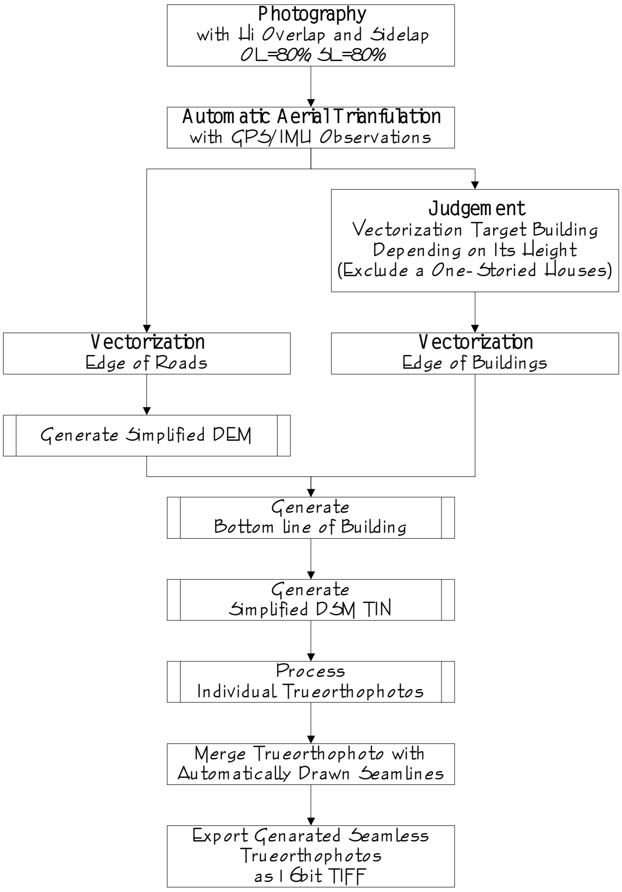


Figure 5. Flowchart of True orthophoto generation method

## 4. PRACTICAL EXPERIMENT

We conducted the experiments based on the method discussed in the above. The details of experiment are as shown in Table 2.

| Items | Description | | |
|---|---|---|---|
| | Case1 | Case2 | Case3 |
| Location | Vicinity of Shibuya Station | | |
| Weather condition | Taken in November, sunny day | | |
| Photography | DMC | | |
| Photography scale | 1:8,000 | | |
| Resolution of image | 9.8cm | | |
| Overlap of aerial photography | 60□ | 67□ | 80□ |
| Side lap of aerial photography | 30□ | 67□ | 80□ |
| True orthophoto generation software | Image station Ortho Pro | | |

Table 2. Experiment work to generate true orthophoto

## 5. RESULTS

Ortho Pro which is the orthophoto generation module of digital photogrammetry system Image station is equipped with the function to generate true orthophoto. This is a function to automatically eliminate the occlusion of building, etc. using other overlapping pictures based on DEM and three dimensional vector data.

After implementing the aerial triangulation, we acquired the edge of streets and external line of two storied and higher building as three dimensional vector data in order to construct DSM. We generated the three dimensional surface model based on it. The external lines of buildings that were not facing with the streets were omitted discretionarily (figure 6, 7).

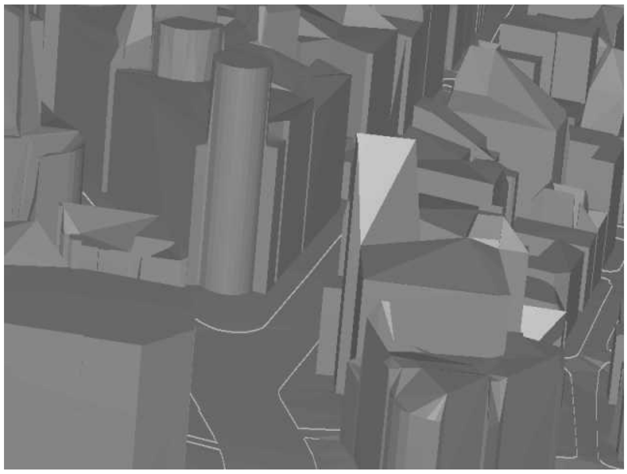

Figure 6. 3-dimentional surface model around High buildings

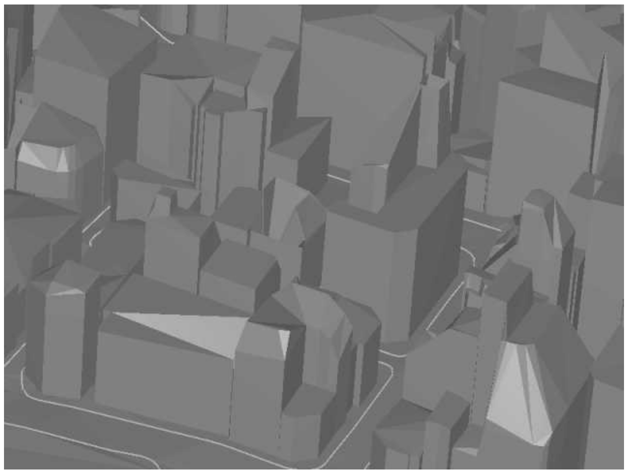

Figure7. 3-dimentional surface model around Narrow Street

Processing of orthophoto generation is divided into rectification, occlusion processing and mosaic, but all of them are automatic processing.

A raw image around high buildings is shown in figure 8.

A part of true orthophoto we generated is shown in Figure 9. Several tiny black areas around wall of buildings can be recognized as occlusion. Photographs are overlapping 25times in maximum, and those occlusions give an example of difficulty of generation true orthophotos.

Figure 8. One of raw aerial photograph around high buildings

Figure 10. One of raw aerial photograph around narrow street

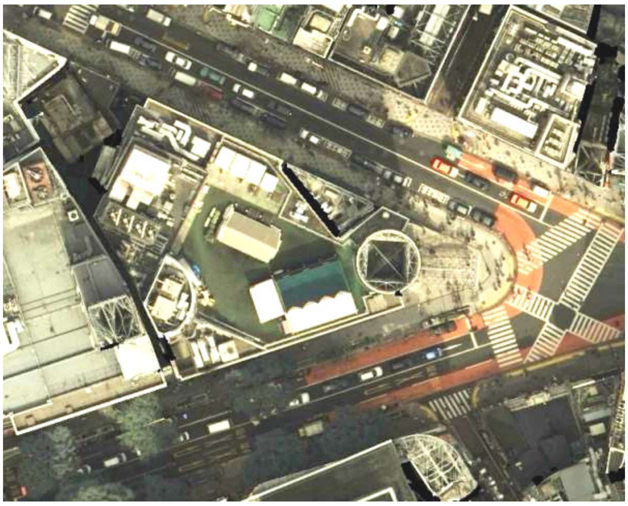

Figure 9. Generated true orthophoto same area as figure 8

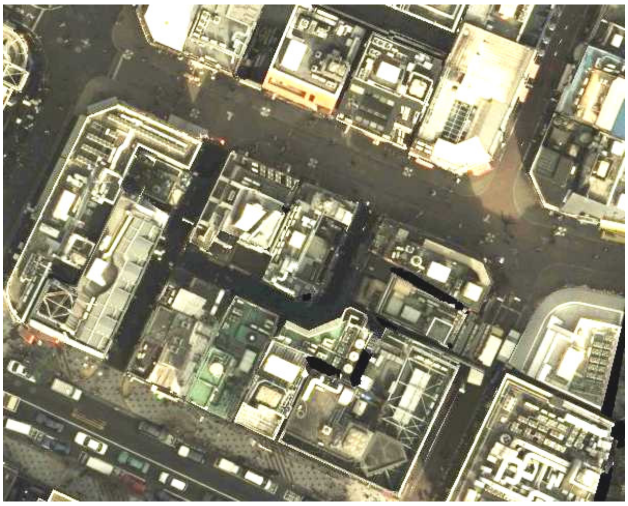

Figure 11. Generated true orthophoto same area as figure 10

A raw image around narrow streets is shown in figure 10. In figure 10, several streets (width 6 meter) are completely covered by building walls. Also Narrow Streets between building and building are too dark in the image for observation objects on the street even they are shown.

A generated true orthophoto is shown in figure 11. Narrow streets are clearly expressed. Also after color and contrast adjustment, it gives us sufficient image quality along the narrow street for plotting work. These images were taken in winter season. So those images prove that system provides sufficient color depth almost all seasons.

## 6. CONSIDERATION

### 6.1 Photography plan using high overlapping ratio

It is possible to reduce the occlusion caused by buildings by increasing the overlap and side lap. The number of photographs taken in a certain time frame has nothing to do with the increase of cost in the case of DMC.

In this study, we made a photography plan with 80% overlap and 80% side lap. In the stage of consideration, we compared the case of 60% overlap and 30% side lap with the case of 67% overlap and 67% side lap applicable to mapping job. Usable extent of photograph in each case is shown in figure 12.

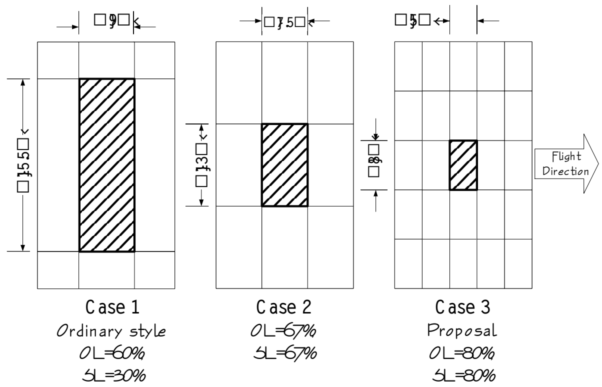


Figure 12. Scope of processing and angle of view of photograph

### 6.2 Effective use of plotting 3 dimensional vector data

DSM with very fine pixel level and three dimensional vector data of building edge, etc. are required for the generation of true orthophoto. Extraction of fine DSM and automatic generation of three dimensional vector data are very difficult technically at present. Therefore, it is practical to acquire three dimensional vector data through manually plotting. As for the job of plotting operator, the cost varies largely depending on the fineness of vector data to be acquired. Some objective yardstick is necessary to acquire three dimensional vector data that can adequately satisfy the purpose. Therefore, we decided following requirements for this product

- The occlusion due to the gap of parallax shall be 50 cm or less in the horizontal distance on the ground.
- The portion other than those facing with the road is not regarded as important.

The length of occlusion caused by building depends on the height of building and the angle of vision of the building on the image.
The height of building of certain angle of view against discretionary allowable length of occlusion is expressed by the following formula (1).

$$H = L / \tan\alpha \qquad (1)$$

Where, $H$ = the height of building
$L$ = Horizontal length on the ground of occlusion of building
$\alpha$ =Angle of view to the building on the image

As the orthophoto is made at fixed reduced scale, the size of occlusion on the image generated may vary according to the difference of relative height from the photographing reference surface even if the horizontal length on the ground is the same. However, since the study object is urban area and the photography is made at large scale, we dared to use the horizontal distance of the ground as the reference for the simplification of processing.
Figure 13 shows the height of building for which the occlusion must be corrected to 50 cm or less. When the angle of view is 3 degrees or less, no correction is necessary for the building with the height of 10 m or less. It is known from this Figure that correction is unnecessary for the building with the height of 3.5 m or less when the angle of view is 8 degrees or less. When the shooting condition is considered based on this requirement, no correction is necessary for one storied building if the overlap is 80% and side lap is 80%, and therefore, the efficiency of plotting work will be enhanced.

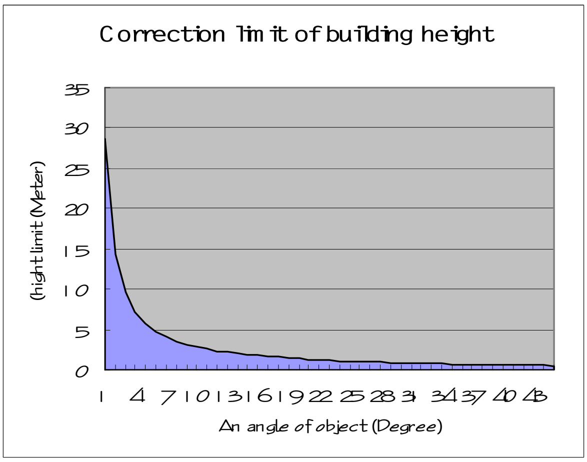


Figure 13. Building for which occlusion must be corrected to 50 cm

### 6.3 High color depth

It is often difficult to take clear picture of the portion shaded by buildings in the aerial photographing of urban areas. In case of the camera using the film, the quality of digital image is sensitively influenced by developing process and scanning process. In addition, the information is normally deteriorated to 8 bits per one band per one pixel due to the restraint of image format compatible to the machine used for scanning processing. On the other hand, DMC stores the information at 12 bits per one band per one pixel without deteriorating the output signal of CCD array. As for the CCD array, there is a tendency that the virtual color depth is lowered as the exposure time is insufficient, but even in the winter season and late afternoon when the intensity of sun beam is feeble, DMC maintains the color depth of image that is far better than the image obtained by filmed camera. For this reason, DMC is very effective for the interpretation of shaded areas (Figure 14).

Figure 14. Example showing the difference in color depth of shaded area between DMC (left side) and filmed camera (right side)

### 6.4 Saving photography cost

Main costs of aerial photography using camera and film are as follows.

- Photo taking expense including chartering fee of airplane
- Cost of film and development
- Printing expenses including the contact printing paper
- Scanning expense for digitalization

On the other hand, the costs other than photo taking expense are unnecessary in case of aerial photographing by DMC, and the saving rate of cost reaches to the range from 50% to nearly 80%. In addition, since photo taking expense is roughly proportional to the flying time of airplane, the unit price of images can be reduced by increasing the number of photos taken within the same time frame in case of photo taking plan with high overlapping ratio.

## 7. CONCLUSION

It was confirmed that the true orthophoto generated by our study has quire an effective image quality as the basic data that can be used for construction control relating to the narrow road. Seeing from the cost performance and image quality of DMC, it has become clear that it is possible to generate the true orthophoto at the almost similar cost of conventional orthophoto by applying simplified processing conforming to the purpose. Large scale is used for the projects which require the true orthophoto. It is assumed that the acquisition of vector data has been required in these projects. It is considered to be possible to more inexpensively generate the true orthophoto by acquiring the vector data taking into account the generation of true orthophotos.

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