LARGE SCALE GEOGRAPHIC INFORMATION ACQUISITION BY 35mm CAMERA

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ABSTRACT

In this study, we try to develop the technique for acquiring the geographic information of large scale at small area efficiently. Above all, so as to indicate the fiducial mark in the non-metric camera, we mounted the glass plate after manufacturing it and extracted the lens distortion coefficients by calibrating the wide-angle lens of which the focal length is 35mm. We loaded the developed semi-metric camera and manufactured the radio control airplane which is suitable for the aerial photography.

We could secure the stablility of control and photography of airplane through diverse flight experiments. And, we analyzed the accuracy by taking the aerial photography with diveres photography altitude and endlap about ground target. As the result, it could be seen that the limit of photography altitude to be able to obtain the topography information with the demanding accuracy is 400m. For the saving of time and expense at the time of measuring the ground control points, we decided the ground control point(GCP) coordinates by using GPS static and kinematic mode.

In addition, by using the built photogrphy system, we photographed 28 sheets of aerial photoes of 3 strip in consideration of demanding accuracy on the area that the real route design is demanded, and made out the digital map by analytical plotter. We could suggest the efficient and economical acquisition method of geographic information of large scale by calculating the profile, cross-section and earthwork volume about the route aligment of newly established road from the obtained digital terrain model(DTM).

1. INTRODUCTION

Recently, much interest is concentrated on the manufacture of digital topographical map which has various merits by getting out of existing topographical map on the basis of the sudden development of the computer and the image processing technique. Especially, digital terrain model (DTM) as the basic drawing for the establishment of GIS is the data form to be required indispensably. So, it is forecast that it will be applied very widely over the whole of civil engineering field. Now in our country, we are acquiring the geographic information at the large area which is necessary for the framing of basic drawing of country, the management of country, the management of environment, the military special goal, the investigation of resource and the topography analysis etc. through the photograph taken by airplane or image taken by satellite(Kang,1993). However, it is the real situation that the method to acquire the geographic information which uses satellite image or aerial photo or topographical map is being used by being limited to the extraction of geographic information of small scale for the most part. And in case of aerial photo, it is difficult to take a photo except the big business of national project and development, the place for the take-off and landing of airplane is being limited extremely. Therefore, the geographic information of large scale which is demanded at the time of development of small area or at the time of execution route design is depending on the conventional method to invest vast manpower expense and time.

Thus, it is the real situation that the framing of profile and cross-section for route design and the succeeding work such as the calculation of earthwork volume as well as the acquisition of topographical information cannot help depending on the conventional manual work.

So the development of technique for acquiring the geographic information of large scale with digital data is being required keenly for the improvement of construction technique of our country.

Thus in this study, we performed the basic study about making the non-metric camera of 35mm into the use for measurement, the establishment of photography system by the small-size airplane of radio-control(R/C), the analysis of measurement accuracy of aerial photo measurement by this system and the efficiency of introduction of GPS technique to the measurement of GCPs. And we try to suggest the efficient acquisition method of geographic information of large scale by 35mm camera by applying this system to the real design of small route.

2. PHOTOGRAPHY SYSTEM

2.1 CAMERA

We chose Nikon F-801 as the camera for loading. This camera is small-size and the radio-control photography is possible. In addition, there are self-timer, auto-winding equipment, and function of exposure compensation etc. and roll-film is used. About camera lens we attached a wide-angle lens of focal length 35mm by considering the economical efficiency of photographing area. As the camera is non-metric camera, we manufactured fiducial mark plate that the cross mark was engraved on plane glass of about 0.2mm thickness and then attached it just in front of film.

And, after exacting radial and tangential lens distortion coefficients and correcting PPA(Principal Point of Autocollimation), PPS(Principal Point of Symmetry) and focal length, we made into semi-metric camera(Oh, 1992).

2.2 RADIO-CONTROL SYSTEM

We manufactured the airplane for radio-control to be able to take off and to land at the object area that the geographic information required directly by considering stability, formness and convenience of transport. And we installed gyro, so that the camera may be maintained vertically regardless of the rolling of airplane. We manufactured the equipment for minimizing the shake of camera by the vibration of airplane engine. And we installed the type to get out of attachment as the loading equipment of camera. As for the model of radio-control airplane we used the airplane of which the wing length is 180cm, the body length is 90cm, the engine is 4 cycle, the weight is 2,800g(state that camera was loaded) as PIPER CUB type and the used radio-control equipment is 7-channel(Kang, 1995).

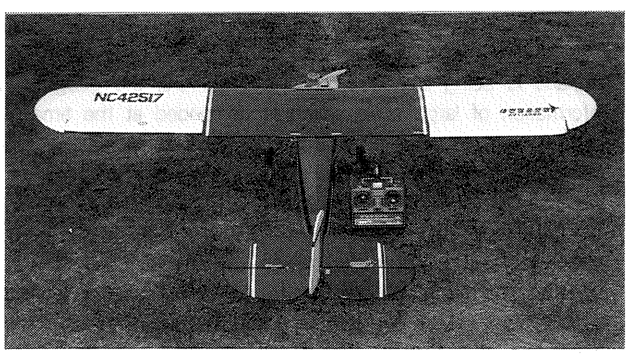

Figure 1. Radio Control airplane

About the developed R/C system we examined all the matters such as the flight stability, the control state of flight altitude, and the speed control state of radio-control equipment, the balanced nature of airplane, the function of rpm control of engine, the motion state of servo, the control state of camera, and the stability of take-off and landing etc. over several times and examined the features such as the image sharpness, the image resolution attendant upon the exposure degree of film, the shutter speed and the open state of f-stop etc.

As the result, for the optimum flight condition wind velocity was below about 5m/sec. And the flight altitude that the flight control was possible with naked eye is within about 400m. And as for the runway the open land of about 5m×20m was necessary. But it was better according as it is wide. For the prevention of shake of image by flight speed and engine vibration it was desirable to photograph by making the speed of camera shutter more than 1/500sec and making the open of f-stop of camera to considerate the depth of field more than f/11. And in accordance with this about the photosensitivity of film it was profitable to use ASA 400 slide film. Photography time was proper from 10:00 a.m. and 2:00 p.m.

3. ACCURACY MEASUREMENT

3.1 PHOTOGRAPHY

So as to examine the accuracy of acquired geographic information we photographed by arranging 88 ground object points with the lattice type of 30×30m interval on the open land and changing into 5 stages from the flight altitude 100~400m. As for film we used Kodak ASA 400 slide film. We photographed by trying the manual operation in accordance with the exposure state after making the shutter speed at the time of photography as 1/500~1/2,000sec and by making the value of f-stop as f/11~f/16. So as to extract the conditions such as the photo scale attendant upon the scale of demanded geographic information and the rate of height of base line(B/H) etc. we photographed by changing the endlap into about 50~80% at each flight height.

3.2 GROUND CONTROL POINT

As for the decision of 3 dimension coordinates of GCPs this paper decided the position of one reference point installed at the object area which was about 13km away from the reference point in the compound of Chungnam National University that the location has already been decided by GPS measurement with the relative positioning. And then about 88 ground object points we observed from the reference point of the object area for 2 minutes respectively by kinematic GPS. As for the observation data we calculated 3 dimension coordinate on the coordinate system of WGS84 by treating with SBP and MBP methods of Trimvec-Plus software.(Park, 1992) About the calculated coordinate we calculated RMSE by using controlling and calculating Trimnet-Plus which is the software of network control. The calculated RMSE is as is in the table 1.

Table 1. RMSE of GCPs by GPS(88 points)

coordinates	X	Y	Z(height)
1σ(m)	0.0056	0.0043	0.0121

About the ground object points we decided the size so that the photography may be made with about 0.03mm in view of a film photographed at the flight altitude 300m. We extracted the exterior orientation parameter of camera through the bundle adjustment theory from the GCP in the photographed film and the coordinate of fiducial mark.

3.3 ANALYSIS

About the film photographed with diverse flight height and endlap, we calculated the 3 dimension coordinate of ground object points and RMSE through the program of bundle adjustment after measuring the machine coordinate with the precise measuring instrument of coordinate. After choosing 1 model of the photographs taken by making the flight altitude different, we calculated 3 dimensional coordinates about 8-15 ground object points with 4 ground control points per model, and table 2 is the RMSE about ground object points at each flight height.

Table 2. RMSE according to flight height

height (m)	RMSE(mm)			
	X	Y	Z	P†
100	22.9	18.3	92.7	97.2
150	34.6	22.3	88.4	97.5
200	43.5	31.4	207.0	213.8
250	59.4	55.1	334.1	343.7
400	87.0	87.3	528.9	543.0

† $P=\sqrt{X^2+Y^2+Z^2}$

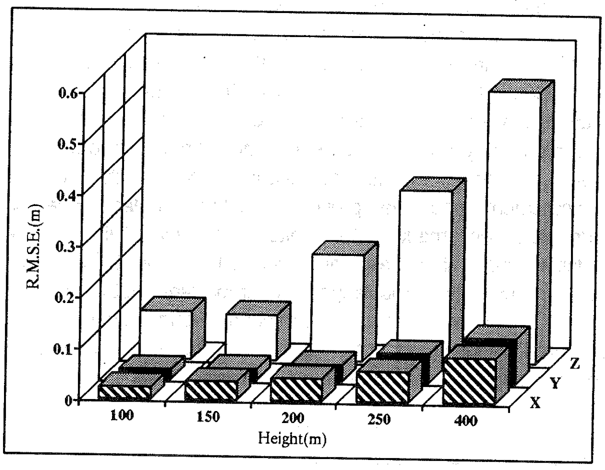

Figure 2. RMSE according to flight height

To illustrate this after comparing it by flight height, it is like the figure 2. The reduction rate of positional error(P) of the result measured from the photo taken by lowering the altitude of about 24%, 40% and 54% with 200m, 150m and 100m on the basis of the flight height, 250m was about 38%, 72% and 72% respectively. And, in case of photographing by rising the altitude to 400m, the increase rate of RMSE of about 60% is showing. To compare this by classifying plane error(X, Y) and positional error(P), the difference of plane position at the flight altitude, 100m was about 29mm, and the positional error was about 100mm.

Table 3. RMSE of ground object points

height (m)	endlap (%)	RMSE(mm)			
		X	Y	Z	P
150	80	47.1	31.7	164.5	174.0
	70	33.6	18.0	77.1	86.0
	60	22.5	15.8	55.1	61.5
	50	21.1	14.6	41.6	48.8
250	80	59.4	55.1	334.1	338.6
	70	33.2	29.3	175.4	180.9
	60	26.3	18.7	153.7	157.1
	50	22.7	16.6	143.3	146.0

In case of photographing by rising the flight altitude to about 30%, 60%, 120% and 250%, the increase rate of RMSE of plane position showed about 40%, 80%, 180% and 300%, and the increase rate of positional RMSE showed the bigger aspect in comparison with the increase rate of RMSE of plane. Thus, it can be seen that the flight altitude has big influence on accuracy. In case the flight altitude, 250m, the scale limit to consider only plane accuracy was 1/500, and the scale limit to consider space accuracy was 1/2000. And, in case of the flight altitude, 400m, we could obtain the map of scale, 1/700 and 1/3000 in accordance with plane accuracy and space accuracy. So, with the photography within the flight altitude, 400m that the naked eye control is possible also, we could obtain the geography information of large scale which is demanded.

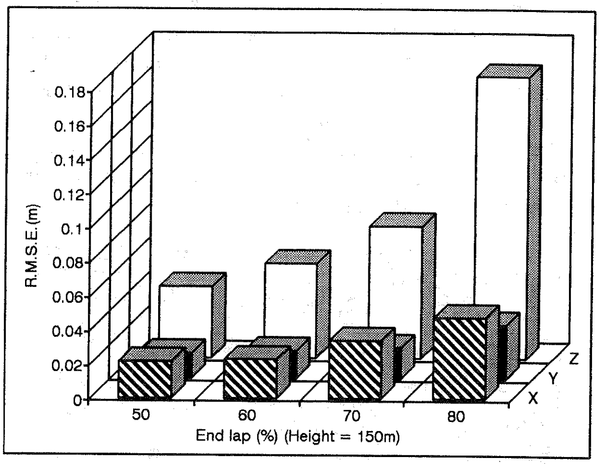

Figure 3. RMSE according to the endlap(h=150m)

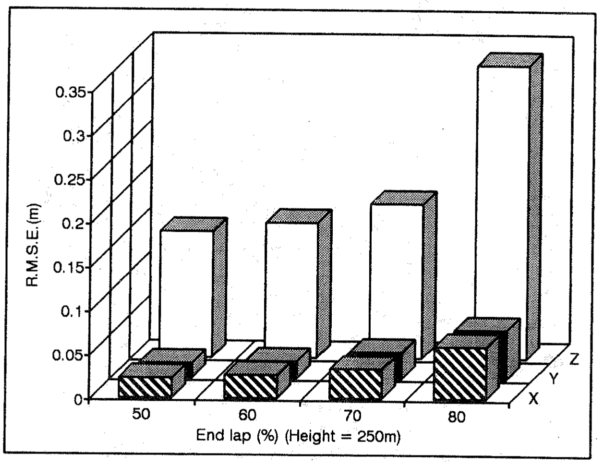

Figure 4. RMSE according to the endlap(h=250m)

Table 3 is the result to have calculated 3 dimensional coordinate of 5-10 ground object points with 3 GCPs and to have extracted the RMSE about 2 photos photographed by making the endlap different at the flight height, 150m and 250m respectively. Then, to compare and illustrate this is like figure 3 and figure 4. As the result to have measured the photo taken by reducing the endlap by about 10% from 80%, the RMSE is showing the tendency that about 44%, 65% and 72% reduce.

This shows that the accuracy of point positioning is improved according as the rate of height of base line(B/H) for photography increases. Then, in case of aerial photography, the endlap over 50% is essential as the ideal endlap is being chosen as 60%, it is considered proper to make the ideal endlap by the developed photography system of radio-control as 60%.

4. APPLICATION

4.1 OBJECT AREA

The object area is that the longitude is E 127° 23′ 00″ and the latitude is N36° 22′ 00″ . Then, we chosed the object area as the existing 1.2km asphalt pavement. The chosen area is the asphalt pavement to link Cheonmin-dong and Kwanpyoung-dong in Taejon city of which the width is about 3-5m and which is not straight. Then, it is in the state that the passing quantity of cars is much and the damage is serious. The starting point of planned construction is a bridge to cross Honam Expressway(Toplib Bridge), and the terminal of construction section, 1 bridge(Pyoungsan Bridge) is being included, and the ground height difference of whole section is about 30m. The planned alignment line chosen in this study is consist of private forest, private paddies and dry fields, and national land.

Figure 5. The scheme drawing for photography

As for the used film, we used ASA 400 Kodak Slide Film from the result of basic study. And, we photographed by fixing the shutter speed as 1/500sec and the f-stop as f/16. So as to acquire the plan and profile map of scale, 1:1200 which are the demanding drawing of execution design, we photographed 28 sheets of photos by planning with 3 strip in consideration of the feature of area which is experiment object, and the scheme drawing for photography is like the Figure 5.

For the manufacture of cross-section drawing and structure drawing that the drawing of largely scale is necessary, we photographed by lowering the flight height partially. From the viewpoint of feature of the photography system, it was difficult to maintain the exact endlap. But, we photographed by maintaining the endlap as about 60-70% and the sidelap as 25-35%. In the photography for mapping, the covering area of 1 photo on the ground is about 306×204m and the base line for photography is about 120m, and the distance between strip was about 160m.

As for the ground control point, total 32 points were used. And some of them are the points that ground targets were installed. And the rest was the natural point which was photographed in photo clearly. About the decision method of 3 dimension coordinates of the GCP and the decision of exterior orientation parameter, this paper performed with the method which is same as the method of position decision of GCP in the basic experiment.

4.2 DATA ACQUISITION

We made out the digital topographical map with the method to make into analytical plotter by compensating the systematic error of photographed photo and by using 3 dimension coordinate and photo coordinate of GCP, and treated by classifying into plane data and altitude data. On the topographical map, we marked the matters about the examination of the present situation of road by recording existing road position, road width and size of structure etc. exactly. And, so as to extract the result of site measurement and the present situation of land use on computer, we made into digital data by digitizing the cadastral map about alignment line. About the DTM to be able to use for calculating the important data of road design such as profile, cross-section, and calculation of earthwork volume etc. by digitally expressing the feature about topogrphy, we extracted it by using PA2000

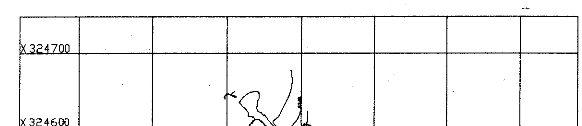

Figure 6. Contour map of object area

In this paper we introduced the GIS, so as to increase the efficiency, by minimizing the time damage and economical damage of abstraction method of data for road design by existing manual work. We tried, so that the establishment of database in this system with the DTM and the basic data for design and the analysis of this data may be utilized for calculating the data for road design automatically. About the data for execution design, we inputted by making out the map of scale 1:1200 for the area of about 50m-150m from the central line of plan design. About 1 bridge out of plan section, we limited the curve diameter of plane alignment

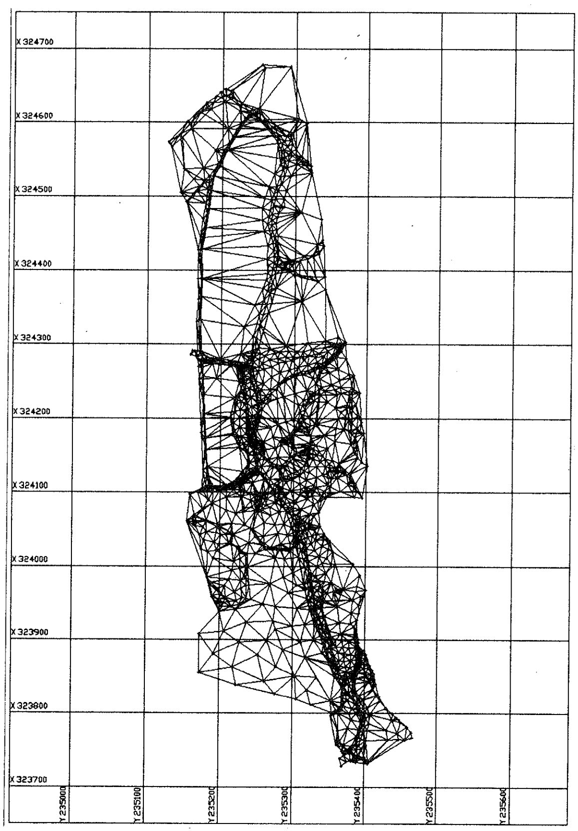

Figure 7. TIN of object area

at the both ends of bridge to 200m or more. And, at the starting point of construction, the relative ground height is high by the given condition of topography and the specialty of pedestrian bridge of expressway. So, in this paper we planned the profile slope by limiting to maximum 6%. From the profile drawing and cross-section drawing, we calculated the data of the slope-changing point in the data of 20m interval and the data of DTM data basically simultaneously.

In this study, we decided 3 units of plane alignment at the object area, and 2 units of profile alignment from each plane alignment. And, we calculated execution design data by chooseing 1 line out of each alignement. We outputted the profile drawing and cross-section drawing about the line which was chosen finally. And, the total earthwork volume was +21,573,748 m^3, and the baking volume was 8,222,278 m^3, and the cutting volume was 29,796,026 m^3 at he chosen line. About the mesurement result of site which is

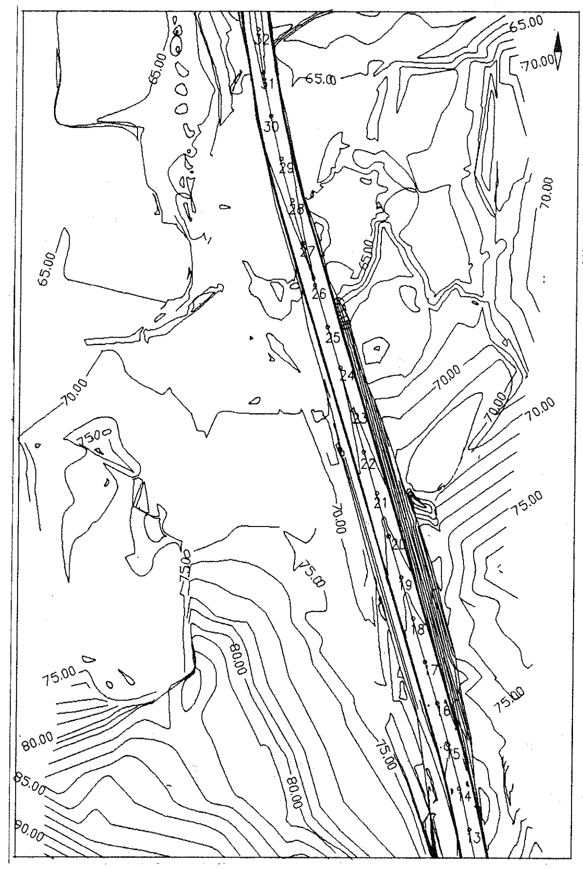

Figure 8. Alignment at digital map

necessary for construction, we outputted indicating the site border etc. after overlapping cadastral map on the digital topographical map.

5. CONCLUSION

This paper examined the applicability by establishing the photography system by 35mm camera and the small size airplane of radio-control and analyzing the accuracy of topographical data photographed with this system. In addition, as the result to have try to apply this to the acquisition of data for the real route design of small area, we could obtain the following conclusion.

(1) Developed photography system may take off and land at the object area that the gepgraphic information is demanded directly. So, we could obtain the geographic information of large scale which is demanded at the time of development plan of small area effectively.

(2) As the result to have introduced GPS technique to the point positioning of GCP, we could obtain the RMSE of X,Y,Z coordinates as about 5mm, 5mm and 12mm, respectively. So, it could be seen that the introduction of GPS technique to the measurement of GCP is efficient.

(3) From the photo photographed at the flight height 300m, the acqusition of design data such as profile and cross-section and earthwork volume etc. about the newly established road was possible by making out the topographical map and DTM and utilizing the GIS. So, it will

able to contribute toward the computerization of the fieid of road design.

(4) If one make the photogrphy system into large size and automatize it so as to aim at the stability and accuracy of air photography and if one progresses the continuous study for the algorithm for the abstraction of design data, it is considered that it will be able to be applied to the fields such as the examination on evironment pollution and the examination on nature disaster etc, as well as construton field widely.

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