

DIGITAL PHOTOGRAMMETRIC SYSTEM USING TOTAL STATION WITH THE SCANNING FUNCTION

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ABSTRACT:

3D data capturing with laser scanner and digital photogrammetry has been established for 3D modeling with texture in civil engineering, architecture, industrial meteorology, cultural heritage etc. However there are several handicaps in those existing methods in developing inexpensive and handy 3D data capturing and processing at the site in terms of the weight, power supply, capturing and processing. Considering those problems involved in the existing methods, a digital terrestrial photogrammetric system using a total station with the scanning function has been developed by TOPCON Co, Ltd. called GPT-8200A which achieves long distance (up to 1.2 km) and geometrically constrained image matching and texture pasting at the site. Scanning of a total station in non-prism or prism-less mode can be performed with a motor drive with a constant pitch of angle each in horizontal and vertical direction, which will result in 3D coordinate measurement. The areas to be measured will be given in the stereo images taken by a digital camera which will be set up near the total station. Triangulation will be made with those control points, measured by the same total station. A 3D model will be generated with TIN model with 3D point clouds measured by the motor driven total station, strip by strip as the scanning proceeds. The texture will be pasted from the orthoimage which will be produced by image matching with geometrically constrained 3D point clouds using TOPCON PI-3000 software. The merit of this system against the existing photogrammetric system will be correctness of 3D measurement with higher accuracy even in low contrast scene areas. The merit against the existing laser scanning will be longer distance of 1.2 km at maximum as compared with about 300m in the case of laser scanner, and higher accuracy without noises as well as inexpensive cost, lighter weight and less power supply. This system will be applied to 2.5D surface models, such as very steep slopes, rocky cliffs, exposed mines, civil engineering structures etc.

1. INTRODUCTION

3D coordinate capturing and 3D modeling with laser scanner or Lidar has been compared with the digital photographic methods. Lidar has an advantage to be able to measure 3D coordinates without triangulation with a high accuracy in a rather short time, though it needs several tie points to connect different 3D models. However, it has those disadvantages of a lot of noises, expensive cost, poor imagery, heavy weight and required power supply. On the other hand, the photogrammetry has an advantage to be able to build 3D model with fine imagery or texture, while it has those disadvantages of triangulation with control points and failure of image matching in low contrast areas.

In order to supplement those disadvantages involved in Lidar and photogrammetric systems, the integration of Lidar and photogrammetric systems has been proposed by many researchers. This integrated method has to solve a shape matching between Lidar and photogrammetric 3D models.

TOPCON Company is developing a digital photogrammetric system using a total station with the scanning function under a concept to maximize the effectiveness of 3D data capturing as well as 3D modeling at the site without post processing after leaving the site.

Though the number of scanning points of this system is much less than the one of the Lidar system, it is not hard to reconstitute the geometry between the total station and the digital cameras at the site. 3D coordinates measured by the total station will be reference or tie points to build a 3D model by image matching

for stereo imagery taken by a digital camera. In future, TOPCON will consider the integration of two digital cameras to be built in a total station.

The scanning speed is also slow, but image matching and texture pasting will be achieved accordingly strip by strip, which will result in shorter processing time in total. It is expected to achieve 3D modeling with texture within three hours in total including setting up those devices and marked target, measuring 3D coordinates of control points, photographing, scanning, triangulation, image matching, texture pasting etc. at the site.

2. CONCEPT OF THE SYSTEM

The concept of the system is the field automation in a word. It means that 3D capturing and modeling with texture will be completed at the site in an allowable time.

The outcome of this system will include the following merits.

- 1) **Portability:** Portability is performed due to the lighter weight as compared with the weight of Lidar system.
- 2) **Less Power Supply:** Power supply is made by ordinary battery installed in a total station and PC with the capacity of three to five hours approximately. An electronic generator or AC supply will not be necessary.
- 3) **Low Cost:** The cost of the system will not be more than 50,000 US dollars, which will be about five times cheaper than the cost of a Lidar.

The merits of the function will be discussed later.

3. CONFIGURATION OF THE SYSTEM

The system is composed of the following devices (see Photo 1).



Photo 1. Total Station, GPT 8200A made by TOPCON

- 1) Total Station GPT-8200A, TOPCON with a motor drive and scanning function at a given pitch of angles in horizontal and vertical direction. The maximum distance of laser measurement is 1.2 km.
- 2) Digital camera with calibrated parameters.
- 3) A personal computer (PC) with digital photogrammetric software of PI-3000 made by TOPCON including bundle adjustment, image matching, orthoimaging etc.
- 4) Marked targets (at least 4 and more) to be set up at the site.

The advantages of the system as compared with Lidar are lighter weight, less power supply (battery will run about three to five hours both in total station and PC) and inexpensive cost (less than 50,000 US\$ including hardware and software).

In the case of conventional photogrammetric system, a total station and/or GPS will be required to measure the control points. Therefore the configuration will not be much different from the conventional terrestrial photogrammetric system.

4. FUNCTIONS OF THE SYSTEM

The system has the following functions.

1) Scanning function and 3D measurement by Total Station

Total Station of GPT-8200A, TOPCON can be manually operated to measure single points as usual and also automatically tracked or driven with a motor drive. Scanning function is added with a given pitch of angle in horizontal and vertical direction.

GPT-8200A has two modes; normal and long mode. The normal mode will work from 3 to 120meters range with coarse measure with the accuracy of $10\text{mm}+2\text{ppmxD}$ in less than 0.3 seconds per point and fine measure with the accuracy of $3\text{mm}+2\text{ppmxD}$ in 1.2 second per point. The long mode will work from 30 to 1,200m range with coarse measure with 100mm accuracy in 0.4 second per point and fine measure with the accuracy of $10\text{mm}+10\text{ppmxD}$ in 1.5-6second per point. Except a special requirement in accuracy, coarse measure will be applied normally because of time saving. In case of coarse

measure of 10,000 points will take about an hour and half for scanning, which will result in all operation and processing in three hours in total at the site.

2) Digital imaging and triangulation

Hand held digital camera will be used to take stereo terrestrial photographs near the set total station. The camera shall be calibrated for the subsequent procedures. The digital imagery will be imported in the memory of the total station as well as PC. The operator will measure the coordinates of those marked targets with the total station and immediately orientation parameters will be determined, which will build the geometric relation between the total station and digital camera stations. The operator has to manually assign the area to measure in a scene of the stereo images on the monitor of total station.

3) Scanning and simultaneous image matching and pasting

From the second row in its scanning, a TIN model can be generated using two neighboring points in the previous row and a point in the current row as well as a point in the previous row and two neighboring points in the current row. Those triangle points with 3D coordinates will be located in a stereo imagery, which will form a triangle in each scene. For the quick look purpose, the texture of the triangle will be pasted to the TIN model by Affine transformation as well as smoothed textured model. In this case, a single photograph and DSM measured by the total station will be enough to produce the quick look orthoimage with less density of 3D points. For the fine pasting purpose, image matching will be made for the left or right triangle to give more dense 3D point clouds. In case of very low contrast area which will be unable to apply image matching, the texture of the triangle will be pasted without dense 3D points. Those image matching will be achieved by TOPCON PI-3000 software system, triangle by triangle and strip by strip. The strip is defined in this paper as a belt-typed polygon which is formed with the previous scanned points and the current scanned points. This procedure will be made by a PC in parallel to the scanning with the Total Station. It means that the final products such as orthoimage will be completed when the scanning is complete. Though the scanning is rather low speed, the total processing will be shorter because the post-processing will not be required.

The advantages of the functions are as follows.

- 1) **On site orientation:** It is possible to integrate the geodetic survey of control points and the photogrammetric triangulation in the system of the total station, after the digital imagery is imported to the total station from the digital camera.
- 2) **Robust image matching and 3D modeling:** 3D measurement with the total station is accurate and stable without noises in most cases. The image matching can be performed in each subdivided triangle formed by TIN model. Blunder will be avoided and the correction will be made locally even if there occurs some mismatching.
- 3) **Parallel processing for scanning and 3D modeling:** PI-3000 will perform 3D modeling or orthoimaging in a PC in parallel to the scanning by the total station. However, the processing will be made strip by strip in order to minimize the processing time of data transfer between the memory of the total station and the PC.
- 4) **Shorter processing time till the final product:** If all times required for the setting up, geodetic survey of control points, stereo photography, orientation, scanning

and 3D modeling or orthoimaging are summed up, it would be shorter than the total time required for Lidar or conventional digital photogrammetric system. The authors estimate the total time in normal case to be less than three hours till the final product at the site without post-processing.

- 5) **Possibility of quality check at the site:** The final product with the pasted texture can be checked at the site, which will be an advantage as compared with Lidar system.

5. FLOW OF THE PROCEDURES

The work flow of the procedures is as follows (see Figure 1).

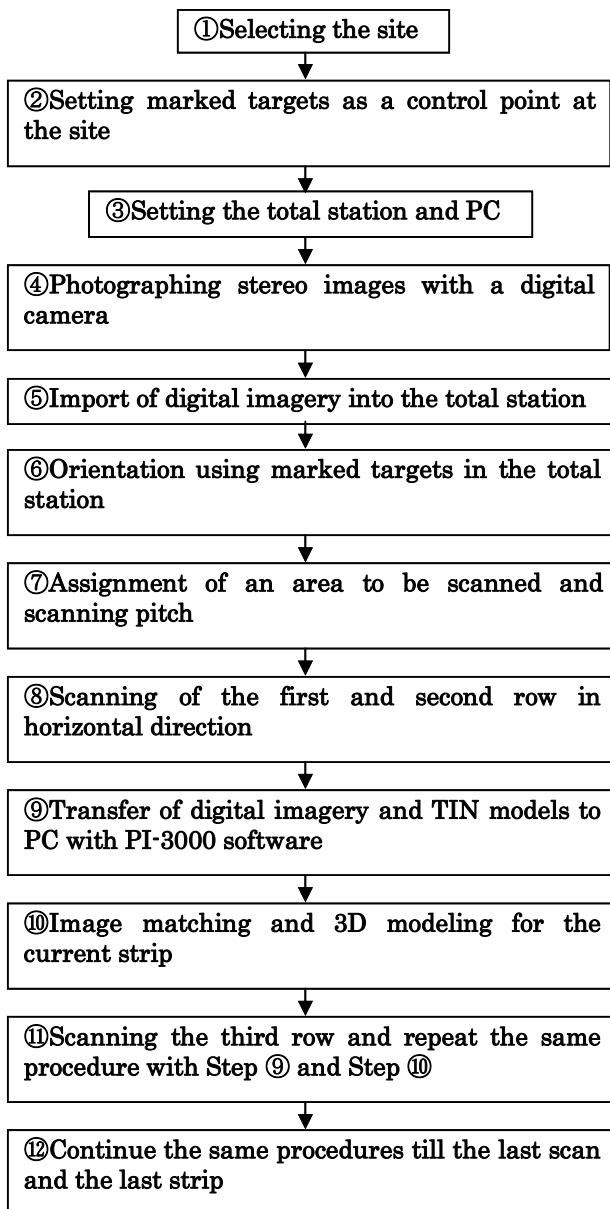


Figure 1: Flow chart of 3D data capturing and processing with a total station of GPT 8200A and a digital camera of CANON EOS Kiss Digital

6. CASE STUDY

A case study was made at the site of a steep cliff of bare rock (see Photo 2) located in Higashimatsuyama, Saitama Prefecture. 9 marked targets were set up for control point. The scanning pitch was set up 30 seconds in arc angle both horizontal and vertical direction. The average distance from the total station and digital camera was about 20 meters. The normal mode with coarse measure with less than 0.3 seconds per points was selected. About 8,800 points were scanned in an hour and half, out of which 6,303 points were selected for generating TIN after avoiding 3D points from grasses and trees.

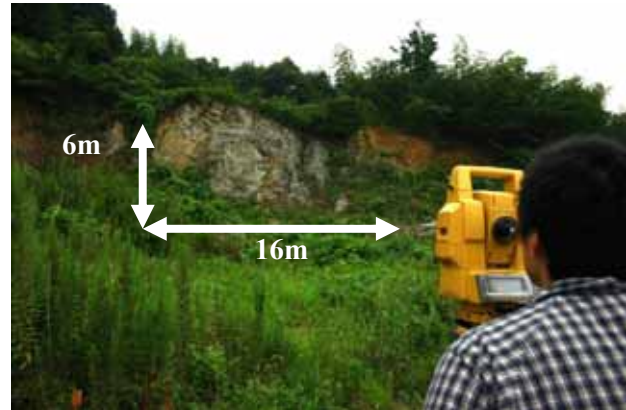


Photo 2: Steep cliff to be measured by GPT 8200A

The required time till the final product of orthoimage with 3D coordinates was as follows.

- 1) Setting the total station and other devices: 10 minutes
- 2) Setting target marks: 20 minutes
- 3) Stereo photography with a digital camera of CANON EOS Kiss Digital with 6.3 million pixels(3088 × 2056), Resolution 7.4 μ m: 10 minutes
- 4) Geodetic survey of those targets and single orientation: 20 minutes
- 5) Scanning and 3D modeling: 90 minutes
- 6) Editing 3D points for avoiding noises: 10minutes
- 7) Miscellaneous time: 10 minutes

The total time from the beginning to the final product was 170 minutes or three hours.

Photo 2 shows the selected site of steep cliff to be measured by GPT 8200A with the size of about 16m wide and 6m high with few grasses and small trees.

Photo 3 shows 6,303 scanned 3D point clouds with GPT 8200A after avoiding noises manually.

Photo 4 shows TIN model with scanned 3D points.

Photo 5 shows TIN model with texture which looks not smooth.

Photo 6: TIN model with smoothed texture without geometric interpolation but only with smoothing of normal vector for generating shading effect.

Photo 7 shows 3D model with only image matching for comparison without use of scanned 3D points, which is a usual product of digital photogrammetry.

Photo 8 shows 3D model with geometrically constrained image matching with use of scanned 3D points obtained by GPT 8200A, which is a final product of the proposed digital photogrammetric system using total station with the scanning function.

Photo 9 shows a comparison between the result from 3D measurement by total station and the one from image matching of stereo imagery. The maximum discrepancy was 20 cm.

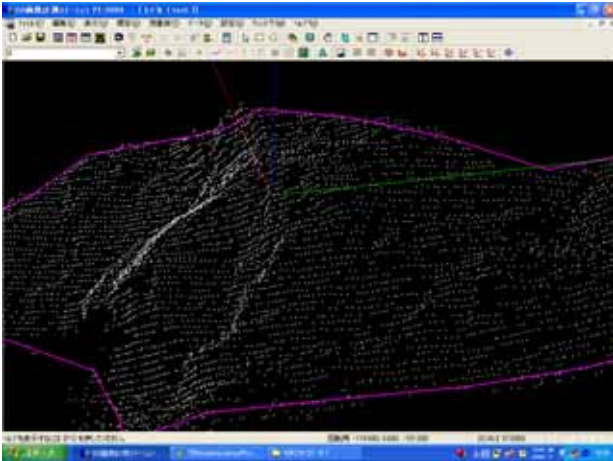


Photo 3: Scanned 3D point clouds with GPT 8200A after avoiding noises manually

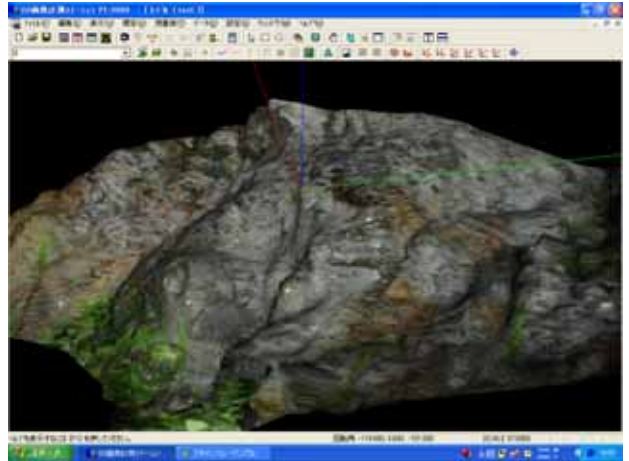


Photo 6: TIN model with smoothed texture

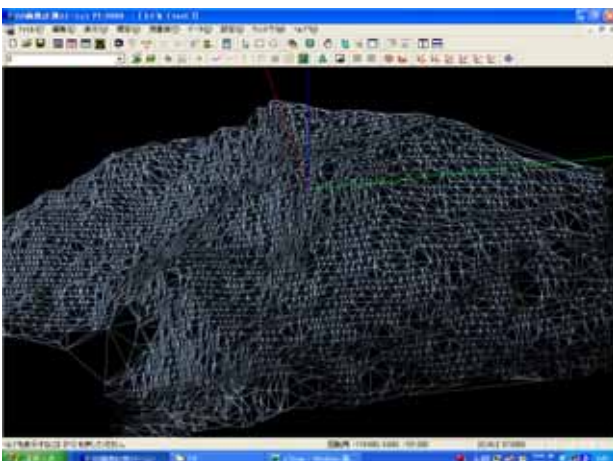


Photo 4: TIN model with scanned 3D points

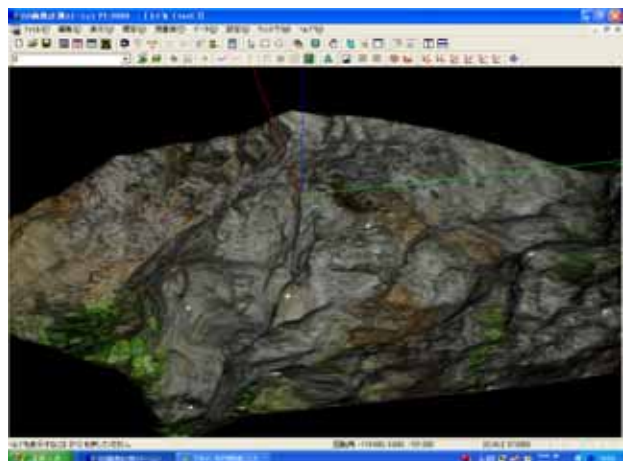


Photo 7: 3D model with only image matching for comparison without use of scanned 3D points

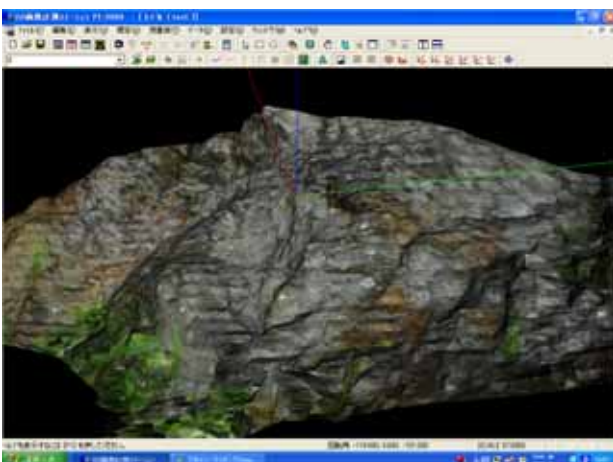


Photo 5: TIN model with texture

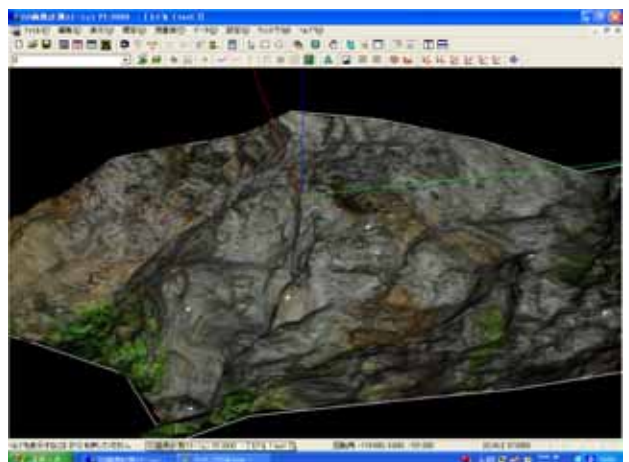


Photo 8: 3D model with geometrically constrained image matching with use of scanned 3D points obtained by GPT 8200A

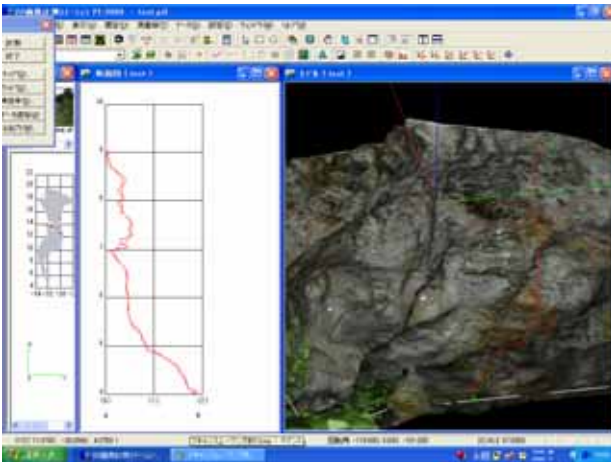


Photo9:Comparison of scanned 3D point and image matching

7. CONCLUSIONS

A digital photogrammetric system using total station with the scanning function was developed for 3D modeling as well as orthoimaging by TOPCON Company, which showed robust image matching in parallel to scanning with a constant pitch of angle in horizontal and vertical direction. Though the scanning is not fast, the total time till the final product will be reasonably short because all processing can be made at the site without any post-processing after coming back from the site. In addition, the cost of the system will be five times inexpensive as compared with ground base Lidar system.