PHOTOGRAMMETRY REASEARCH AND DEVELOPMENT IN CEPC*

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Abstract

In the released CDR of Circular Electron Positron Collider(CEPC), the circumference of storage ring is 100Km. And at the same time, the precision requirement is still the same as the hundreds meter collider: 0.15mm. The conventional laser tracker survey method can not meet the precision and efficiency requirement at the same time. The photogrammetry method is noncontact and flexible, easy to realize automatic measurement; and its measurement precision is promising . So this paper covers the application research of the photogrammetry in CEPC tunnel survey and magnet fiducialization.

INTRODUCTION

The length of super collider CEPC is far longer than any existed ones. The mount of magnets and cavities is huge, automatic fiducialization is very important; the scale of tunnel has reached geodetic scale, but the component density is hundred times higher. So the alignment and maintenance efficiency is very important. In spite of such large scale, the precision requirement is still as high as the hundreds meter scale collider. In the conventional laser tracker survey, there is a paradox between precision and efficiency, because its contact and single point measurement pattern. The photogrammetry method can cover dozens of targets, and it is noncontact, easy to realize automatic measurement. But the accelerator tunnel is not the conventional photogrammetric circumstance. We carried out several research and development work.

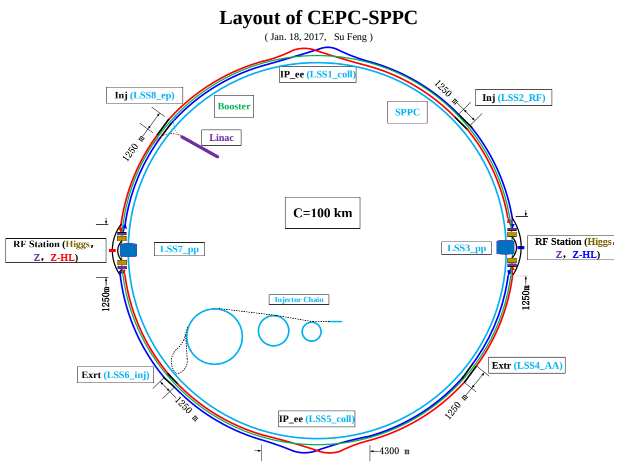

Figure 1: Layout of CEPC-SPPC

PHOTOGRAMMETRIC ALGORITHM

In order to get familiar with every aspect that influences precision, whole process of algorithm was run through.

Target extraction

The distribution of gray level affects the target centre extraction precision a lot. So it's very important to separate target from background. Canny method and break point identify algorithm are combined together to realize target edge extraction. Ellipse fitting and weighting centroid method are used to get targets' centre. 0.05 pixel precision and 97% recognition rate can be achieved.

Coded target cognition

Retro-reflective target has no other information but the image coordinate in every station, if we want to correspond the same points in different images, we have to orient every image first. Coded targets are used to realize this function.

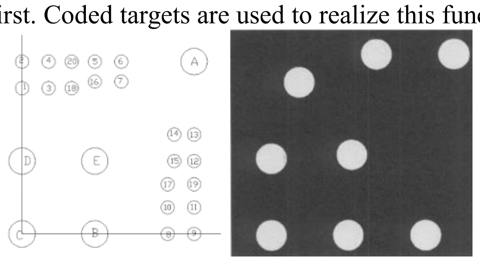

Figure 2: Coded target

There are five template points in every code, cross ratio invariability is used to recover the target coordinate system, the other three code points can fall into right position, then we can get the coded value. The cognition algorithm is shown in Fig.3.

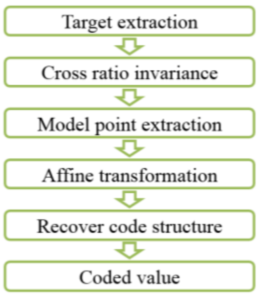

Figure 3: Coded target cognition algorithm

Bundle adjustment

Bundle adjustment for photogrammetry is especially huge, because the mount of image station itself is very huge. We used relaxation algorithm to simplify the whole adjustment process, as shown in Fig. 5.

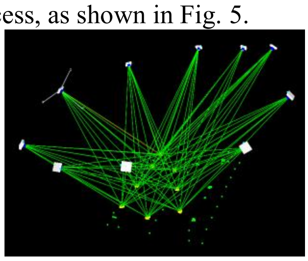

Figure 4: Bundle adjustment

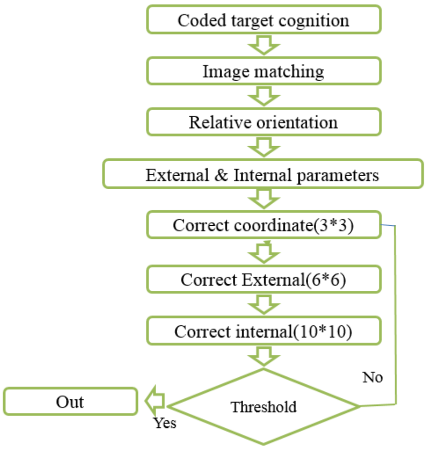

Figure 5: Relaxation bundle adjustment algorithm

TUNNEL SIMULATION

Accelerator tunnel is not the conventional circumstances of photogrammetry, so experimented tunnel is set up to check the influence factors. The set up are shown in Fig.6.

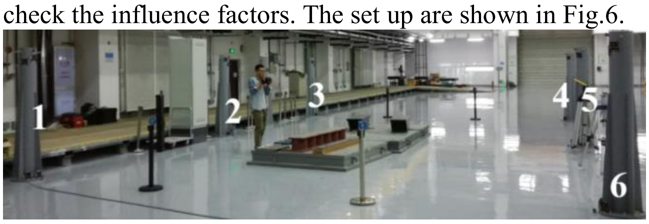

Figure 6: Tunnel simulation set up

There are 6 2m pillars, 3 in a row, with an interval of 7m.

The first two experiments are carried in this setup. Because space between pillars are very big, only few targets can show in each image, so there are not enough common points to match image stations in most cases. We can get 1mm precision in this setup.

Then we changed the setup into only one row pillars, 5 pillars, 3.5m interval. We can get 0.8mm precision.

In experiment 5, there are 9 pillars with 1.75m interval, finally, 0.37mm precision is achieved. Experiments results are shown in Table.1.

Table 1. Tunnel simulation results

Experiment	X	Y	Z	Total
1	0.83	0.37	0.43	1.01
2	1.06	0.38	0.44	1.21
3	0.59	0.20	0.30	0.69
4	0.57	0.21	0.59	0.84
5	0.28	0.12	0.21	0.37

Because tunnel is a long narrow space, it is very important to take pictures from both sides of the tunnel, otherwise there will be not enough common points to match images. So we constructed a temporary 3D coded target to realize this function.

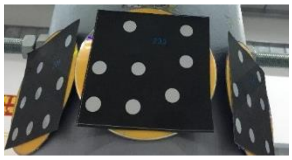

Figure 7: 3D coded target

CSNS TUNNEL EXPERIMENT

Real tunnel survey experiments are carried out in CSNS tunnel. Survey strategy is separated into two steps. Step 1 : local magnet measurement, step 2: long range control measurement.

Step 1 focuses on the magnet fiducials. Step 2 uses 3D coded target working as control network to connect local magnet stations together.

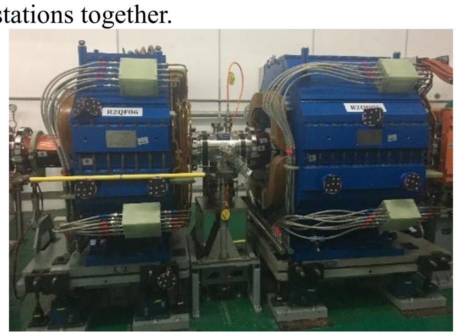

Figure 8: Local magnet measurement

Figure 9: Long range control measurement

¼ RCS tunnel, about 70m×4m×2m are measured, including RCS control network points and 10 magnets. The results are compared with laser tracker measurements.

Table 2. CSNS tunnel experiments

	X	Y	Z	Total
1	0.226	0.282	0.214	0.420
2	0.288	0.266	0.209	0.445
3	0.333	0.220	0.189	0.442
4	0.173	0.271	0.187	0.372
5	0.259	0.256	0.181	0.407
6	0.204	0.205	0.185	0.343

The tunnel measurement precision can reach 0.4mm in 70m range, but according to the theoretical precision of the camera, we can get 0.2mm at least.

Then we compare the hemisphere we used with Brunson 1.5” target.

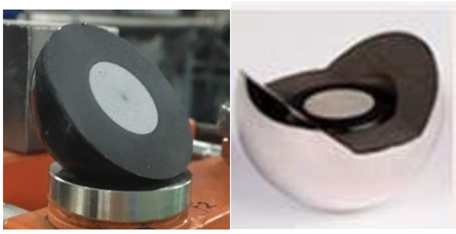

Figure 10: Hemisphere and Brunson targets

Table 3. Precision difference between Hemisphere and Brunson targets

X	Y	Z	Total
0.162	0.097	0.032	0.192
0.212	0.124	0.054	0.251

So hemisphere targets' precision affect measurement precision a lot. More precise targets need to be developed.

MAGNET FIDUCIALIZATION

Fiducializaiton is another important job in accelerator alignment. Brunson 1.5" target and coded targets are combined together to realize this function. 1.5" target seated on a holder to measure the polar and end plane, as shown in Fig.11.

Fig.11 Polar and end plane measurement

Fig.12 Fiducialization setup

Table 4 Fiducialization precision

	Laser tracker			Photogrammetry			Error		
272QCF1	-398.86	753.24	349.68	-398.89	753.24	349.68	0.03	0.00	0.01
272QCF2	-596.63	753.41	-350.19	-596.63	753.44	-350.16	0.00	-0.02	-0.03
272QCF3	597.94	753.30	-350.67	598.00	753.36	-350.61	-0.06	-0.05	-0.06
272QCF4	397.38	753.12	349.69	397.44	753.09	349.75	-0.05	0.03	-0.06

Compared with laser tracker measurement, photogrammetry can reach 0.06mm precision.

SUMMARY

In the CSNS tunnel experiment, 70m tunnel only cost 2 hours' time, if we use laser tracker it will cost at least one day. So the photogrammetric method is high efficient, and its precision is promising. More precise target need to be developed, the relation between network interval and precision need to be systematically analysed.

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