Teaching Practice of Automatic Measurement with Georobot

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Key words: teaching practice; automatic measurement; Georobot;

SUMMARY

Traditional teaching practices of surveying, control surveying or other surveying courses are mainly operated by manually from reading, recording, limit value checking to data calculation and comprehensive analysis. This way plays an important role in bringing up lots of excellent surveyors, but it has some disadvantages, such as time-consuming, low efficiency, making reading or calculating errors easily, and being scarce of integration of inside and outside work. Nowadays, our teaching practices of some surveying courses must also keep up with the times and be reformed.

In recent years, thanks to georobot's special capabilities, such as high-precision, real-time, automatic observation, automatic recording, automatic searching, tracking, identifying and collimating accurately targets etc., it has been applied in many fields, such as topographic survey, industrial survey, especially in the large-scale non-supervisor, all-day, all-orientation deformation automatic monitoring of dam, bridge, landside, underground, tunnel or other high-building etc.. These special capabilities and applications of Georobot make it possible and necessary to set up a new course——Teaching Practice of Automatic Measurement with Georobot, which will provide new conditions and views for the practicer and make them understand and use advanced instruments and technologies more skillfully, efficiently.

This paper introduces the elementary requirements, time arrangement, operation arrangement, practice content, tutorial guidance contents and necessary instruments of this teaching practice. And it introduces the definition, measurement principle of Georobot. Then operation steps are discussed in detail. Eventually, it indicates that setting up this practice course will make perfect and satisfactory effect.

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1 INTRODUCTION

Science and technology of surveying and mapping is a key subject with the main characters of engineering course. Its main courses of the surveying engineering major includes surveying, surveying adjustment, cadastral surveying, geodesy, engineering surveying and high application surveying etc.. Additionally, it has some main teaching practices, such as surveying teaching practice, control surveying teaching practice, digital surveying and mapping teaching practice etc. These teaching practices are named traditional ones in this paper, they are mainly operated by manually from reading, recording, limit value checking to data calculation and comprehensive analysis. And they plays an important role in bringing up lots of excellent surveyors, but there are some disadvantages, such as time-consuming, low efficiency, making reading or calculating errors easily, and being scarce of integration of inside and outside work. Nowadays, our teaching practices of some surveying courses must also keep up with the times and be reformed.

In recent years, thanks to georobot's special capabilities, such as high-precision, real-time, automatic observation, automatic recording, automatic searching, tracking, identifying and collimating accurately targets etc., it has been applied in many fields, such as topographic survey, industrial survey, especially in the large-scale non-supervisor, all-day, all-orientation deformation automatic monitoring of dam, bridge, landside, underground, tunnel or other high-building etc.. These special capabilities and applications of Georobot make it possible and necessary to set up a new course——'Teaching Practice of Automatic Measurement with Georobot', which will provide new conditions and views for the practicers and make them understand and use advanced instruments and technologies more skillfully, efficiently.

This paper introduces the elementary requirements, time arrangement, operation arrangement, practice content, tutorial guidance contents and necessary instruments of this teaching practice. And it introduces the definition, measurement principle of Georobot. Then operation steps are discussed in detail. Eventually, it indicates that setting up this practice course will make perfect and satisfactory effect.

2 INTRODUCTIONS OF THE TEACHING PRACTICE

The characteristic of 'Teaching Practice of Automatic Measurement with Georobot' is a practical teaching procedure. The main aims of this teaching practice are training the students having knowledge of advanced instruments and technologies about automatic measuring and learning using automatic measuring instruments and systems.

Following, the elementary requirements, time arrangement, operation arrangement, practice content, tutorial guidance contents and necessary instruments of this teaching practice will be discussed.

2.1 Elementary Requirements of this Teaching Practice

Elementary requirements of this teaching practice are as following:

- having knowledge of the basic principle of Georobot and its application for automatic deformation monitoring of engineering construction;
- mastering the basic principle, application situations and the general operation process of two automatic deformation monitoring systems with Georobot, viz. 'Georobot mobile network automatic measuring and data processing system' and 'fixed Georobot automatic deformation monitoring system'.

2.2 Time Arrangement

The time arrangement of this teaching practice is: totally three Class periods. Thereinto, there is one class period for the teacher's tutorial introduction, explanation and guidance, and the other two are arranged for outdoor visit and practice. In the process of outdoor visit practice, 15 students are united into a group, the automatic deformation monitoring demonstrating operations of 'Georobot mobile network automatic measuring and data processing system' and 'fixed Georobot automatic deformation monitoring system' is done in the open places (such as the Youyi Square in Wuhan university).

2.3 Practice Contents

Practice contents include:

- Monitoring method and general process of mobile network automatic measuring and data processing;
- Monitoring method and general process of fixed automatic deformation monitoring

2.4 Tutorial Guidance Contents

The teacher's tutorial introduction, explanation and guidance contents include:

- Component and basic principle of Georobot;
- Component and application of mobile network automatic measuring and data

processing system;
- Component and application of fixed automatic deformation monitoring system;
- Differential data processing method of fixed automatic deformation monitoring system;
- Brief using introduction of two automatic monitoring systems.

2.5 Necessary Instruments

The necessary instruments have:
- One Leica Georobot, installed mobile network automatic measuring software;
- One portable computer, installed mobile automatic network data processing system and fixed Georobot automatic deformation monitoring system.;
- One communication cable;
- Several tripods and prisms;
- One measuring umbrella;
- Several steel tapes.

3 INTRODUCTIONS OF GEOROBOT

3.1 Definition of Georobot

Georobot is one kind of intelligent electronic total station, also called as measurement robot, which can replace man to automatically search, track, identify and collimate accurately targets, and get some data information, such as angle, distance, three-dimensional coordinate and image. It's developed based on ordinary total station, integrated with step motor, visual image system composed of CCD image sensors, intelligent control and application software.

3.2 Technical Components of Georobot

The technical components of Georobot is made up of coordinate reference system, manipulator system, actuator, computer/controller, closed loop control sensors, decision making, target finding and integration of sensors. The coordinate reference system of Georobot is spherical one, viz. the telescope can move around a vertical and horizontal axis, and can find target in any direction from 0°□360° in horizontal plane and from 0°□180° in vertical plane. The main performance of the manipulator is the ability to control the rotation of Georobot. The actuator makes the step motor move by converting electrical, hydraulical, or pneumatic energy into motion. The computer/ controller has three main functions, viz. starting and terminating motions of the manipulator in desired sequence and at desired points, storing position and sequence data in memory, interfacing with other systems. The closed loop control sensors transfer feedback signal to actuator and controller for tracking measuring or precision targeting. Decision making is designed for finding target, such as using the method of emulating how humans would characterize the image(called as heuristic analysis) or analyzing pieces of an object (called as syntactic analysis) for image matching. Target finding is designed for collimating targets accurately, generally with the methods of windowing, thresholding, region segmentation, maximum searching of the intensity of a light beam, square spiral etc.

All observations are obtained by integration of sensors, including sensors of distance measurement, direction measurement, temperature measurement and air pressure measurement etc.

3.3 Basic Principle of Georobot

After image formation, image acquisition and image processing, visual image system composed of CCD image sensors is designed for automatic tracking and collimating accurately targets operated by computer and controller, thereby information of length, thickness, width, orientation, planar and three-dimensional coordinates about object or pieces of the object can be gained, and then its configuration and changes with time can be gotten.
Generally speaking, after accepting certain a measuring task, surveyors firstly make operation design, using the basic measuring knowledge and according to measuring task and exist instruments, and identify and understand targets with sensorium, then operate instruments and complete measuring task according plan. While Georobot can identify the targets in the measuring world by CCD image sensors and other sensors, and make rapid operations of analyzing, judging and reasoning, self-controlling, auto collimating and reading for replacing totally manual operations.

4 INTRODUCTIONS OF TWO AUTOMATIC MONITORING SYSTEMS

4.1 Mobile Network Automatic Measuring and Data Processing System

4.1.1 Brief Introduction of System

'Georobot mobile network automatic measuring and data processing system' is technically designed for plane control surveying and automatic deformation monitoring. It can complete outdoor automatic measuring of high precise plane control network and deformation monitoring network of with one or more Georobot, which always have multi observation numbers re-measuring. This system is adapt to all plane control network measuring, such as traverse network, triangulateration network, triangulation network or trilateration network, its operation mode and limit errors fit the requirements of our national exist criterions, and the limit errors can automatically checked, if different limit errors are set according to different requirements, the all measured data will be fit the limit error demand after automatic measuring. Outdoor measured data can be imported into the automatic data processing software, and then the final data results of control network or deformation monitoring points will be gotten expediently. It can actualize automatization from outdoor data measuring (such as automatic searching, identifying and collimating accurately targets and making auto angle and distance measuring) to indoor result calculation and output, improve the outdoor and indoor working efficiency markedly, lessen manpower greatly, make gross error impossible, reduce demands for man and instrument of traditional method (once man can make simple operations, he can take outdoor or indoor work).

This system has two parts: viz. outdoor data measuring and indoor data processing.

4.1.2 Components of System Hardware

According to outdoor data measuring and indoor data processing, the hardware components of 'Georobot mobile network automatic measuring and data processing system' have:

(1) Outdoor data measuring
- One Leica Georobot;
- Several observation prisms.

(2) Indoor data processing
- One computer (Win95/98 or NT operation system);
- One graphic plotter/printer.

4.1.3 Components of System Software

According to outdoor data measuring and indoor data processing, the software components of 'Georobot mobile network automatic measuring and data processing system' have:

(1) Outdoor data measuring
- Network automatic measuring software

(2) Indoor data processing
- Automatic data processing software
- Leica Office software

4.2 Fixed Automatic Deformation Monitoring System

'Fixed Georobot automatic deformation monitoring system' is designed for automatic deformation monitoring and data processing of kinds of engineering with Georobot. It can make real-time monitoring, automatic measuring and deformation process showing of all monitoring points. It's adapt to automatic monitoring of dam, bridge, landside, underground, tunnel or other high-building.

4.2.1 Components of System Hardware

The hardware components of 'Fixed automatic deformation monitoring system' have:
- One Leica Georobot;
- Several observation prisms;
- One computer (Win98 or NT operation system);
- One communication cable;

4.2.2 Components of System Software

The software components of 'Fixed automatic deformation monitoring system' have:
- Fixed automatic deformation monitoring software

5 DIFFERENTIAL DATA PROCESSING METHOD

There are three types of points in fixed automatic deformation monitoring system, viz. base points, station points (also named working points) and monitoring points. Considering the base points and station points for direction are stable and unchangeable, the observations of horizontal angle, vertical angle, inclined distance may be changing thanks to the influence from the meteorological change and the movement of zero direction of horizontal circle. Therefore, it proper dada processing method must be given for correcting the systematic error, due to outer factors. Differential data processing is a method of using base point data for correcting the observations of monitoring points. It will be discussed as following.

5.1 Differential correction of horizontal angle

Differential correction of horizontal angle can weaken the influence of atmosphere refraction and the movement of zero direction of horizontal circle. The horizontal angles of the base points in measuring cycle j (j=1, 2,$\cdots$, m, m is the times of measuring) are taken for base azimuth. The horizontal angles of n (n is the count of base points, generally n =1or 2) base points are respectively denoted as $Hz_{ij}(i=1,2,\cdots,n)$ in this measuring cycle, and those are respectively denoted as $Hz_{ik}(i=1,2,\cdots,n)$ in the measuring cycle k at the same measurement station. Then the correction value δ of horizontal angles between measuring cycle *k* between measuring cycle *j* is as follows:

$$\delta = \frac{\sum_{i=1}^{n}(Hz_{ij} - Hz_{ik})}{n} \qquad \text{□1□}$$

Afterwards, the horizontal angle of each deformation point *P* in measuring cycle *k* (denoted as $Hz_P^{'}$) plus the correction value δ is the final horizontal angle (denoted as Hz_P) after the differential correction of horizontal angle.

$$Hz_P = Hz_P^{'} + \delta \qquad \text{□2□}$$

5.2 Differential Correction of Inclined Distance

The meteorological correction is up to 10 ppm when the temperature has changed 10.0ºC. Therefore, the influence of distance measuring caused by the meteorological change can't be ignored. It's required that the thermometer and barometer should be placed on each measuring station and target point for getting meteorological data. But in most case, it's not economical. Considering the measuring station point and base points are steady, the change of inclined distances from measuring station point to base points among different measuring cycles can be regarded as the influence of outer conditional and meteorological change. The working of measuring meteorological data may not be done if the differential correction of the inclined distances from measuring station point to base points has been calculated based on this change of inclined distances.

The inclined distance from measuring station point to n base points is respectively denoted as d_{i1} (i=1,2,…,n)in the first measuring cycle, while those in measuring cycle k is denoted as d_{ik} (i=1,2,…,n). Then the proportional coefficient Δd of meteorological correction is calculated as follows.

$$\Delta d = \frac{\sum_{i=1}^{n}\frac{d_{i1} - d_{ik}}{d_{ik}}}{n} \qquad \text{□3□}$$

If the inclined distance of monitoring point P is $d_p^{'}$ in measuring cycle k, then the inclined distance d_p after differential correction is:

$$d_p = (1 + \Delta d) d_p^{'} \qquad (4)$$

5.3 Differential Correction of Elevation Difference

In the polar coordinate measurement, differential correction of elevation difference is made to decrease the influence of elevation difference caused by the effect of earth curvature and refraction. The elevation difference from measuring station point to n base points is respectively denoted as h_{i1} (i=1,2,…,n)in the first measuring cycle, while those in measuring cycle k is denoted as h_{ik} (i=1,2,…,n). Under the Condition of steady measuring station and base points, the correction value *c* of the effect of earth curvature and refraction is as follows.

$$\begin{cases} c_i = \dfrac{h_{i1} - h_{ik}}{(d_{ik} \cdot \cos\alpha_{i1})^2} \\ c = \dfrac{\sum_{i=1}^{n} c_i}{n} \end{cases} \qquad (5)$$

Thereinto: α_{i1} is the vertical angle of base point *i* in the first measuring cycle, d_{ik} is the inclined distance of base point *i* in the measuring cycle *k*. After calculating the correction value *c*, the differential correction formula of trigonometric elevation difference between monitoring point *P* and measuring station point is expressed:

$$h_{pk} = d_{pk} \cdot \sin\alpha_{pk} + c \cdot (d_{pk} \cdot \cos\alpha_{pk})^2 \qquad (6)$$

In above formula, α_{pk} and d_{pk} are respectively the vertical angle and inclined distance of monitoring point *P* in the measuring cycle *k*.
After differential correction of inclined distance and elevation difference, the inclined distance is denoted as d_p, the elevation difference is denoted as h_p ,then the calculation formula of horizontal distance D_p is:

$$D_p = \sqrt{d_P^2 + h_P^2} \qquad (7)$$

6 PRACTICE STEPS

The main operations of instrument and software are made by teacher, and the students can visit and take part in it. Following, practice steps are given.

6.1 Mobile Network Automatic Measuring and Data Processing System

1) Check the network automatic measuring software (named as AutoMeas) is installed in Georobot or not. Check automatic data processing software is installed in computer or not. Check data storage card is inserted in Georobot or not, data communication cable is taken or not, volume of Georobot battery is full or not.
2) At an open place (such as the Youyi Square in Wuhan university), three or four observation points are selected, the distances among points are about 100m. Then Georobot are put on one observation point and prisms are placed on other points, composing simple triangle or geodetic quadrangle network, see as Fig.1 and Fig.2.

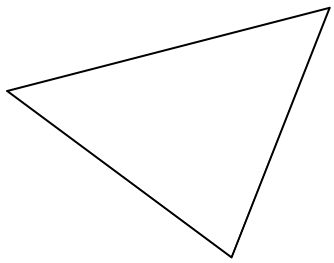

Fig.1 triangle network

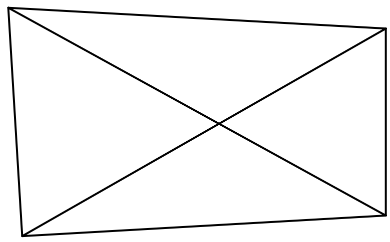

Fig.2 geodetic quadrangle network

3) Start up AutoMeas, make direction and side observation, the observation steps are as following:

- Place Georobot on the station point, make centering and leveling, then power on Georobot and open the AutoMeas software.
- Set up all limit error values of this measuring, such as zero adjustment error,2Cerror, direction error,etc.□
- Initial observation (the purpose of initial observation is getting initial sketchy location information of observation points). Measure all observation points, and input observation points name and prism height into corresponding files in the PCMCIA card.
- Station set up. Set up observation number, distance observation time, instrument height and station name, etc.
- Backsight and direction. Before automatic observation, the work of backsight and direction must be done, viz. collimate the first point and read, record the horizontal angel value.
- Automatic measuring horizontal angle. After setting up limit error values, station and backsight and direction, Georobot will automatic measure horizontal angle according to

initial observation order, check all limit error of one observation number, if there are some over-limit observations, it will re-measure.

– Check limit error among different observation numbers. When there are over-limit values among different observation numbers, it requires manual adjustment to select which observation number re-measured. After setup re-measured observation number, it will be re-measured.

– Distance measuring. There are two distance measuring modes, viz. automatic measuring and half-automatic measuring.

4) Move Georobot to other points, redoing all 3) steps, until all points are observed.
5) Connect computer and Georobot with communication cable. Start up Leica Office software in computer, then copy all files in the AutoMeas folder of PCMCIA card to computer.The observation data files of every station have initial observation value file(working name.ini), station setup file(working name.sta), angle observations file(working name.hzd) and distance observations file(working name.dis).
6) Startup automatic data processing system, the main interface is shown as fig.3, then make following operations:

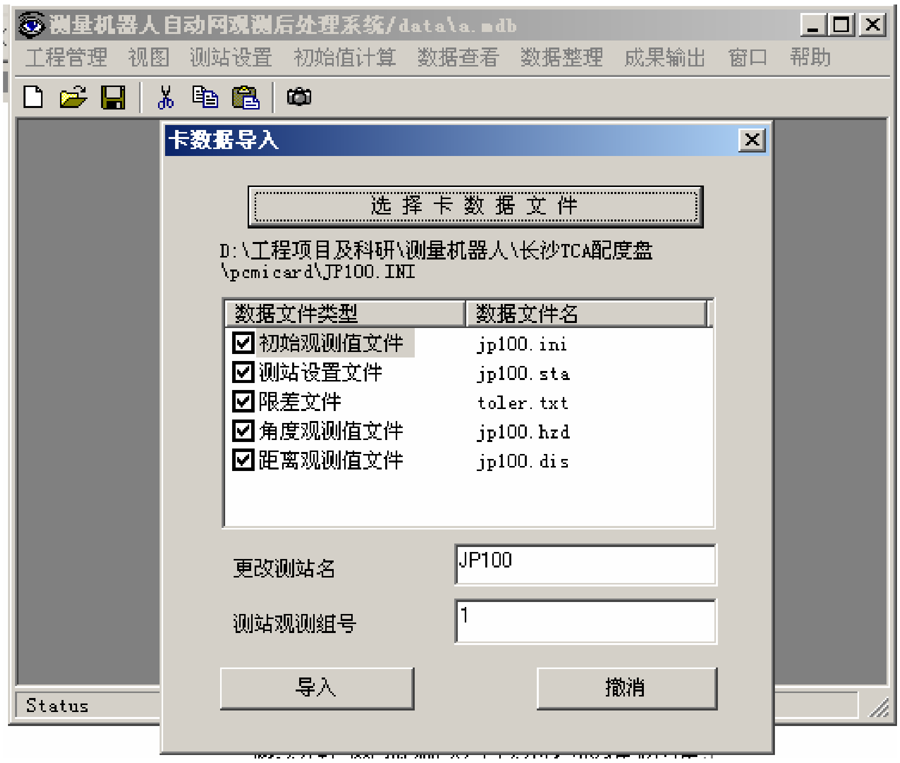

Fig.3 the main interface of automatic data processing system

- Project management. New a project, then import observation data of all stations into it.
- Data processing. Including original angle data processing, checking limit error among observation numbers, original distance data processing, seeing results of angle processing and station.
- Recording book output. According to the ordained format of criterion, angle and distance data will be outputted to Excel as the standard outdoor observation recording book.
- Adjustment calculation.

4.2 Fixed Automatic Deformation Monitoring System

1) Check the automatic deformation monitoring system (named as Geo_DAMOS) is installed in computer or not. Check data communication cable is taken or not, volume of Georobot battery is full or not.
2) At an open place (such as the Youyi Square in Wuhan university), select a steady place for setting up station, and then select two or three deformation monitoring points, the distances among them are about 100m. Then Georobot are put on one observation point and prisms are placed on other points, composing a simple fixed automatic deformation monitoring system.
3) Connect computer and Georobot with communication cable, start up software Geo_DAMOS, its main interface is shown as fig.4.

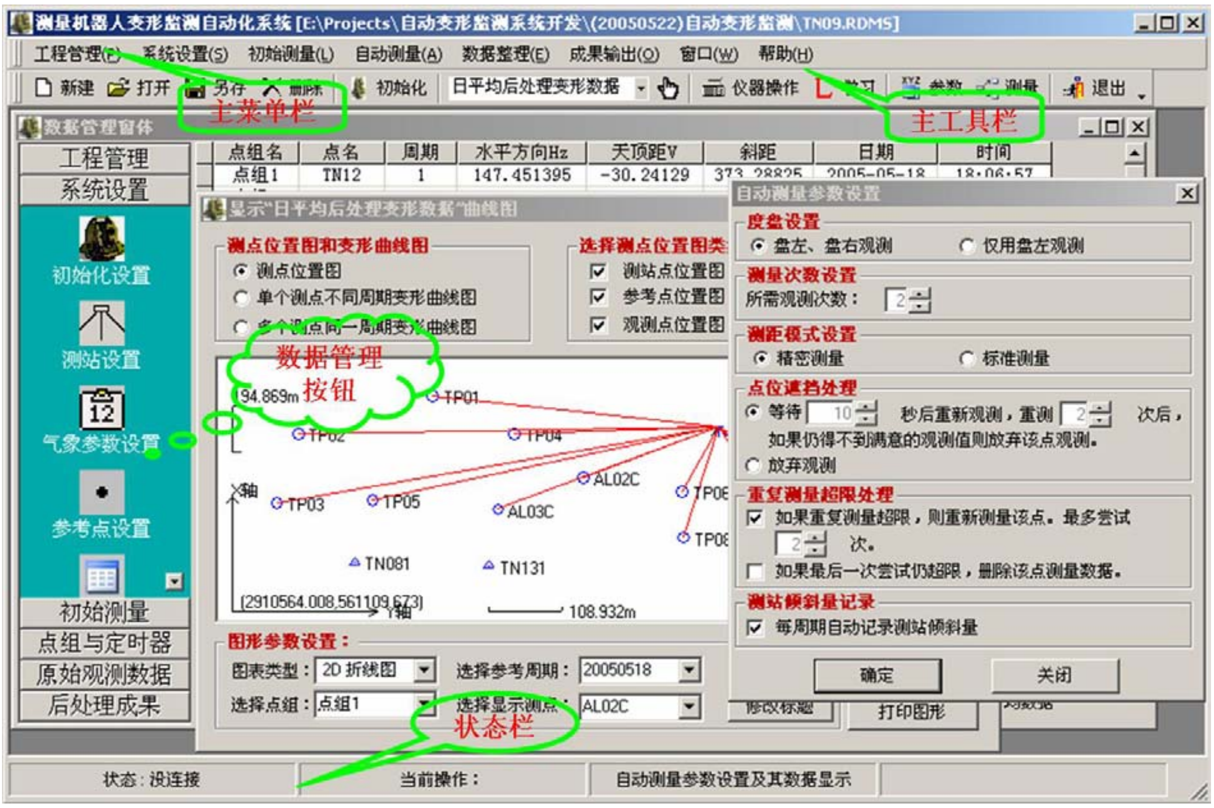

Fig.4 the main interface of fixed automatic deformation monitoring system

4) According following function modules, make operations and setup orderly.

This system is composed of following function modules:

- Project management, designed for managing deformation monitoring information;
- System setup, designed for setting up instrument and measuring reference frame;
- Initial measuring, designed for learning measuring of deformation monitoring points in order to get the initial location information;
- Automatic measuring, designed for automatic measuring parameters setting up, flow control of automatic measuring and automatic measuring;
- Data processing, designed for processing original data and managing final results;
- Final result output, designed for outputting final results.

5) Initial measuring. After setting up project information and system information, initial measuring should be done, collimating every deformation point, measuring and saving its initial location.

6) Group deformation points. New timer for saving automatic observation starting time and time interval between cycles, then connect timer and point group.

7) Make automatic deformation monitoring, after several measuring cycles, the deformation value will be calculated and the deformation figure will be shown.

7. PRACTICE RESULTS

7.1 Mobile Network Automatic Measuring and Data Processing

- Output original observation recording book, including horizontal angle, distance and vertical angle;
- Output adjustment file;
- Closure error calculation and adjustment calculation

7.2 Fixed Georobot Automatic Deformation Monitoring

- Output original observation
- Output deformation analysis result.

8. CONCLUSIONS

As a new intelligent total station, Georobot has some superior capabilities, which makes it be applied in many fields successfully, while it has less used for teaching practice course. And the traditional teaching practice courses have their own disadvantages, thus this paper points out the possibility and importance of setting up a new one, named as ‘Teaching Practice of Automatic Measurement with Georobot’, which will provide new conditions and views for the students and make them understand and learn how to use advanced instruments and technologies more skillfully, efficiently.
This paper introduces the elementary requirements, time arrangement, operation arrangement, practice content, tutorial guidance contents and necessary instruments of this teaching practice. And it introduces the definition, measurement principle of Georobot. Then two systems are introduced, and the differential data processing methods are discussed, then operation steps are narrated in detail.
Setting up this practice course will make perfect and satisfactory effect.

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BIOGRAPHICAL NOTES

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