Application of Network TPS Intelligent Monitoring System in Subway Structure Deformation Monitoring

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Abstract: In this paper, the concept of 'Intelligentized Total Station Network Monitoring System' is proposed, which comprised many Automatic Total Station to monitor wide area structural deformation.The System is composed of equipment and software. In the end, depict the locale project and optimizing design of Guangzhou metro structure deformation. By the factual application, this system is steady and reliable can be best used in auto deformation monitoring

With the fast development of modern science and technology, as well as constant coming forth of new, automatized and intelligentized instruments for surveying and mapping, it has become more and more convenient for surveying and mapping workers to construct automatic surveying systems. Endowed with capabilities of automatic target-finding and precise alignment, the automatic total-stations of TCA series produced by Leica Corp. have shown great advantages and promising future of application. Connecting the total station and computer via modern communication techniques, and implementing automatic surveying, recording, data processing and report forms outputting, leads to surveying automatization and integration in real sense. It could reduce human and material resource consumption, and what's more, it can liberate surveyors from onerous labor of traditional surveying work. Currently, using multiple real-time differencing method[1][2], the polar coordinate surveying system including a total station has been efficiently applied in projects like dams, bridges and tunnels. However, inter-visibility and short maximum target-identification distance have limited the application of a single total station within automatic surveying of small regions. For surveying of large areas, just a single instrument cannot cover the whole area, and its application is obviously limited. In this paper, we have proposed a concept of Intelligentized Total Station Network Monitoring System, which extends the application of automatized total station in monitoring and other fields by constructing a network monitoring system composed of multiple total stations via computer communication techniques.

1. Hardware of the Network Monitoring System

The system in terms of hardware includes multiple total stations, circular prisms, power-supply and communication system, workstation computer, network commuters, switch and central server computer. If remote monitoring is requested, the Internet and remote monitoring computer should be added. The system structure is shown in Fig.1.

The system work flow can be described as follows. The remote monitoring computer controls the central server computer via the Internet. The latter communicates with workstation computer via the network switch, and the workstation computers are connected with total stations via power supply and communication system so as to control the total stations to make mutual automatic alignment surveying and surveying on corresponding prisms. Theoretically, the amount of total stations that can be linked to the system is unlimited. As the system can monitor a large area, parts or all of the total stations might be located in deformation regions, as a result of which, the coordinates of the point of total station are not fixed. Therefore, the coordinates of the point of total station must be known before observing the prism of deformation point. Prisms are mounted on handles of every total station and pegged onto handles by special device. The difference of the center of instrument and the center of the prism mounted on its handle must be determined so as to precisely acquire the coordinates of every monitoring stations. The optimal position of prism is that its center and the center of instrument are located on the same plumb line, which can be adjusted by special device to an accuracy within 0.1mm. Then the height difference of the two centers are precisely measured. Thus the relations of the two centers are revealed. Therefore, the precise coordinates of the monitoring point of total station can be calculated by observing the prisms mounted on their handles within a network of total stations, which can supply precise station coordinates for every total station to automatically monitor its prisms with in a consistent coordinate system of network monitoring system.

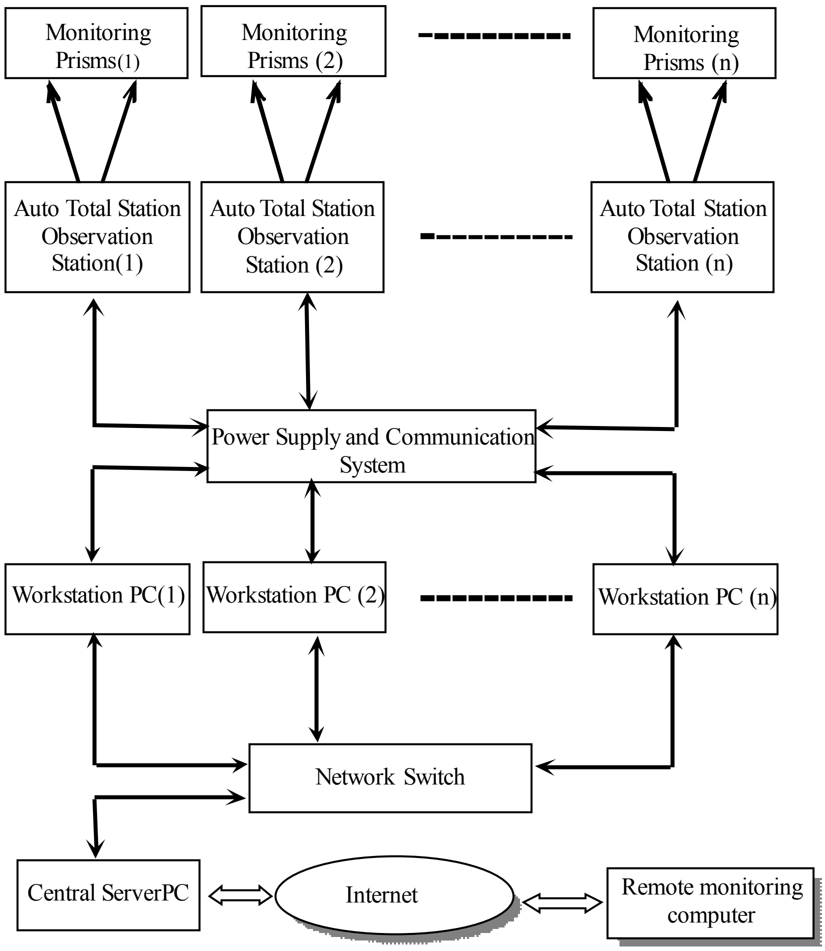

Figure 1: Intelligentized Total Station Network Monitoring System

2. System Software

The system software comprises two parts: dynamic benchmark real-time surveying software and deformation points monitoring software.

2.1. Dynamic Benchmark Real-Time Surveying Software

The essence of the dynamic benchmark real-time surveying software is the fully automatic surveying of the control net. The software is used to acquire the real-time coordinates of every station point.
When the point of instrument is located in deformation region, the coordinates of the station point must be duly acquired, so the station point must be incorporated in the control net. However, in automatic surveying of the control net, the station itself is also the mirror station of other station points. Therefore, the stations should be coordinated to guarantee the cooperation of observing stations and mirror stations. There are several key problems the software must solve, which are as follows

Workflow control of surveying, which means surveying can be made on stations of order set at random. For one station, there are two kinds of operations. One is that when observation is made at this station, the mirror station to be observed by this station should face it. The other is that on the same baseline, the mirror stations not to be observed should back on to it.

Network control, which means how the central server computer controls the total stations via workstation computers.

Data processing, which means that data processing and adjustment method must serve to improve the accuracy of the network.

To implement network control, the dynamic benchmark real-time surveying software includes central server computer software and workstation computer software.
(1) central server computer software
The central server computer software is mainly used to control surveying flow, send operating orders to workstation computers according to the flow, receive hint messages and surveying data sent back by workstation computers, and take corresponding steps based on returned messages. Within the central server computer, databank management of surveying data and adjustment computation of the control net are also completed. The central server computer software is the human-machine interface for dynamic benchmark real-time surveying. All the surveyors' intent of measurement is set up within the central server computer.
(2) workstation computer software
The workstation computer software mainly executes the instructions sent by the central server computer, and send corresponding instructions to the automatized total stations accordingly, and then receive the surveying data and information returned from the total stations, and send the processed results to the central server computer. In the workstation computer software, the only operation is the setting of port number, with the port number being the unique address for the central server computer identification and connecting workstation computers.

2.2. Deformation Point Monitoring Software

The deformation point monitoring software includes automatic monitoring software and databank management software.
(1) automatic monitoring software
Installed in workstation computers, the automatic monitoring software uses the real-time coordinates of every station points acquired by the dynamic benchmark real-time surveying software, controls the automatized total station to make automatic surveying based on required

observing time, observing points, and observing limits, and transmits the surveying results to the management databank of the central server computer in real time. The automatic monitoring software has been optimized on most functions of single total station deformation monitoring software[1][2], and on the format of databank as requested by the network monitoring system. In addition, when deformation monitoring is made within a tunnel, if a lot of deformation points were to be monitored, there would be multiple prisms in the field of view in the identification of remote targets of total station. In this case, the function 'little viewing field' must be started of the total station, and the surveying scope must be greater than 15 meters. Normal viewing field is for points within 15 meters. Therefore, the function of switching between big and small viewing field according to the point has also been added.

(2) Databank management software

Installed in the central server computer, the databank management software is used to manage the data returned by every workstation computer, solve the changes of deformation points via real-time multiple differencing method[1], and display the data in curve figures as well as report form outputs as requested by users.

3. Application of the System in Subway Monitoring

For a subway station of Guangzhou City, real estates construction makes it necessary to dig deep foundation pit (neighboring the subway tunnel), which is about 360m long. As Figure 2 shows, the south end of the subway is reinforced concrete sinking pipe tunnel, and the north end of the subway is shield-like tunnel. The two sides of the platform have a geology of silt, hardpan, strong mantle rock, and a high water level. To ensure a safe operation of the subway, and considering construction, design validation as well as data accumulation, etc, there must be monitoring of the safety of the main structures like subway platform, sinking-pipe tunnel and shield-like tunnel that are most possible affected within the digging area of the deep foundation pit. And at the same time, it must be ensured that the train operates under no influence of monitoring. As the monitoring area is very large, and the tunnel within monitoring area has an S-like shape, one single total station can not see through the whole tunnel, and therefore the optimized scheme makes use of 6 total stations, which constitute the 'intelligentized total station network monitoring system'.

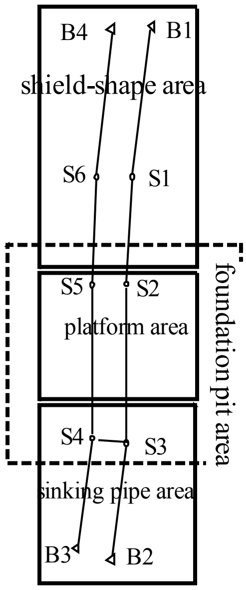

Figure2: Sketch of Monitoring Layout of Guangzhou Subway

3.1. Technical Index of Monitoring

For the deformation of subway structure as well as tunnel, the project puts that for the displacement, subsiding and transverse displacement, the alarm level is 10mm, and that steps are to be taken or act schedule is to be made when 15mm is reached, controlling it below 20mm. As requested, the maximum deformation should not be greater than 20mm. According to common sense, the observation error of the deformation point position must be less than 1/10 of allowed deformation index[4]. Therefore, the accuracy of the position observation of deformation points should be better than 2mm.

3.2. Dynamic Benchmark Control Net

The benchmark points, observation points and deformation points are all located within the second underground floor of the subway tunnel. The locations of benchmark points and observation points are shown in Fig.2, in which S1~S6 are observation points, and B1~B4 are benchmark points. 2

automatic total station TCA2003 and 4 TCA1800 are mounted on the 6 observation points.
The benchmark point that is located on monitoring station S1 of the up line is B1, and the benchmark points of station S2 are S1 and S3, and S3, B2. The benchmark point of the station S4 of the down line is B3, and the benchmark points of station S5 are S4 and S6, and S6, B4. Among these points, S1~S6 are located within or near the deformation area, and B1~B4 are far away from the deformation area and can be viewed as benchmark points. Then setting dynamic benchmark control net is to measure the coordinates changes of S1~S6 versus B1~B4. As it is intervisible between S1~S4, the up line connected with the down line makes up of non-oriented three dimensional traverse network.

3.3. Deployment and Design of Monitoring Profile

On the whole deformation area 21 monitoring profiles are settled along the up line and down line respectively. In the north end shield-like area there are 13 profiles and each has 5 monitoring points; in the platform area there are 5 profiles and each has 4 monitoring points; in the south end sinking-pipe area there are 3 profiles and each has 4 monitoring points. There are 194 monitoring points totally.

3.4. System Control Center

Being nerve center of the monitoring system, the system control center is settled in the control room on first underground floor, with one central server computer and 6 workstation computers. With ADSL installed in the control center, any place in the world may have control over the system via the Internet.

3.5. System Operation

The system has been operating since the end of 2004. By observing 2 to 8 periods everyday, more than 700 periods of monitoring data have been acquired up to May, 2005. From the statistical analysis of the acquired data, the average accuracy of every period of the weakest points S2 and S5 of the dynamic benchmark surveying has reached 0.8mm, and the maximum point position error of every period is 1.5mm. The average accuracy of other points of every period has reached 0.5mm, and the maximum point position error is 1.4mm. After real-time differencing of deformation points, the accuracy of the weakest point position is better than 1mm. Putting the two points together, the surveying accuracy of the weakest point position of deformation is better than 1.8mm and could be higher if daily averaged. The results are near perfect and satisfy the demands of subway structure deformation monitoring.

4. Summary

The Intelligentized Total Station Network Monitoring System inherits the superiority of the monitoring system of single total station, and extends the application fields of automatic total station monitoring system. It solves the problem of automatic monitoring of large deformation area, especially the monitoring of subway monitoring. The system has the following features and advantages:

(1) Implementation of complete automatization of dynamic benchmark control net surveying and deformation points monitoring. Under the conditions of normal operation of trains, the system can make intelligent judgement and processing of temporary veiling of targets, which enables it to make continuous automatic monitoring for 24 hours. It avoids the shortcomings of traditional methods, saves large amount of human power and resources, and guarantees a real-time safe operation of the subway.

(2) Incorporation and coordination of dynamic benchmark control net surveying and deformation points monitoring. By automatic control net adjustment after control net surveying and sending the dynamic benchmark coordinates data to the management software of monitoring software in real-

time, and thus providing reliable coordinates of observing stations for the automatic monitoring of deformation points, the system realizes seamless linkage of data.
(3) Solution by appending scale parameter in the control net adjustment, and multiple differencing method in solution of deformation points coordinates. The two points can improve the accuracy of surveying by eliminate or reduce a lot of errors to a maximum extent, simplify additional devices like meteorlogical equipment, and thus implement fully automatic and highly accurate monitoring in real-time under computer control.
(4) Functions like real-time data processing, data analysis, report form output, curve figure display of deformation quantity can provide multiple data for monitoring engineering.
(5) Making use of techniques like network data transmission, control and management, remote monitoring, and automatic alarming of abnormal values makes it convenient to implement system management, maintenance and timely decision-making, and lowers the total operation costs.
The Intelligentized Total Station Network Monitoring System gains technical superiority in automation and high accuracy by integrating techniques like automatic surveying, serial port communication, network communication and remote monitoring, which will make it appear in more and more deformation monitoring fields.

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