The Application of Satellite Navigation System in Deformation Monitoring

ChangPing Lu*
State Key Laboratory of Rail Transit Engineering Informatization (FSDI), Xi'an, Shaanxi Province, China

*Corresponding author e-mail: luchangping64@xueshumail.cn

Abstract. Global satellite navigation system has become one of the top technical means in the world. The use of satellite navigation in many fields, such as deformation measurement, civil navigation, search resources, geodetic survey, auxiliary precision engineering monitoring and so on, can play its high precision positioning, all-weather monitoring and other technical characteristics. At the same time, satellite navigation system is combined with modern information technology, Internet technology and so on, which realizes the automatic collection, transmission, processing and analysis of safety monitoring data, and the application efficiency is maximized. The present situation and application of satellite navigation system to monitor the deformation of high-rise buildings are studied in this paper. Nowadays, more and more high-rise buildings in the world have sprung up like bamboo shoots. Therefore, how to realize the satellite navigation system to carry on the all-weather, the high precision, the high efficiency monitoring to the high-rise building, carries on the diagnosis to the dangerous signal in time, timely carries on the forecast to the future possible danger and the timely stop loss, this has the very important realistic significance. By reading the literature, the paper expounds the concepts of satellite navigation system, satellite navigation system and Internet technology in detail. The paper mainly takes the high-rise building scaffold as the object of deformation monitoring, and expounds the advantages and reliability of GPS as high-tech for deformation monitoring of high-rise buildings. Finally, through experimental design, the recognition of GPS technology by comparative method reflects the inestimable position of satellite navigation technology.

Keywords: Satellite Navigation Systems, Deformation Monitoring, Internet Technology, High-Rise Buildings

1. Introduction
Because of many fields in the world, such as geodetic survey, water conservancy and hydropower engineering, crustal movement, transportation and so on, the scale of safety monitoring and automation technology are becoming more and more accurate, and the traditional means of deformation monitoring are abandoned. GPS technology has the most advanced observation
technology in the world. High-rise buildings as the research object, high-rise buildings through various force majeure factors will inevitably deform, affecting the normal use of buildings and people's life safety [1-2], satellite navigation system has played a greater advantage in various fields, the application of GPS technology to deformation monitoring of high-rise buildings will become a more accurate technical means. As a result, it is of great significance to study the key technology of deformation monitoring data processing [3] large-scale high-rise buildings under the new situation.

Since the birth of the GPS system, foreign countries have first begun to study the application of GPS technology. Through the establishment of crustal deformation monitoring network, relevant scholars provide support for seismological research, regional surface subsidence monitoring, crustal kinematics and other fields. At the global and regional deformation monitoring field, countries around the world have built regional or national GPS continuous operation monitoring network to monitor crustal movement, forecast earthquakes and volcanic eruptions. The study of using GPS technology to monitor crustal movement in China is basically synchronized with the world. Relevant scholars have established crustal movement velocity fields in China and its surrounding areas by using GPS monitoring network data. The most basic crustal movement characteristics in China are obtained by analysis. GPS technology has become a conventional technical means in the field of deformation monitoring of large-scale projects, it is widely used in reservoir dams, large bridges, high-rise buildings and other projects. In addition, GPS technology has been gradually adopted in landslide detection and ground subsidence in mining areas.

With the gradual improvement of the space constellation of satellite navigation and positioning system, the opening of more signals and the provision of free public services to the whole world, satellite navigation and positioning system will play a more and more important role in the construction of national economy, the field of high precision positioning and the international stage [4-5]. Along with the development of society, the safety performance of the building should also be taken into account while paying attention to the construction. Therefore, the use of GPS navigation system to monitor the deformation of high-rise buildings has become an urgent task. Various risk factors are checked and monitored, various deformation are evaluated objectively, the probability of future risk is predicted and stop loss is stopped in time to prevent people's life and property safety.

2. Proposed Method

2.1. GPS Positioning technology

GPS has become the most accurate positioning technology in the world at present, and has become a geodetic survey, deformation measurement of large engineering and other different fields, even in the life of everyone closely related, affecting our travel, work, study. The GPS monitoring method has made a revolutionary breakthrough compared with the traditional measurement means, it has realized the remote accurate positioning technology; adapts to the outside bad climate, the interference factor influence is small, greatly reduces the manpower and material resources use [6]; in addition, GPS can realize the long-distance, fully automatic, does not depend on the human monitoring, the work efficiency greatly enhances; With the continuous improvement of information technology and Internet technology, all kinds of hardware and software data processing have been guaranteed, GPS positioning technology has been practiced and applied, for the benefit of mankind, many fields have been widely used [7]. For satellites, the satellite's antenna is directed in the direction of the earth, and the solar panel intersects the direction of the sun, so that the unit vector of the coordinate axis of the satellite-solid coordinate system in the inertial coordinate system can be represented by the satellite position vector and the solar position vector:

\[ e_x = \frac{x_{SAT}}{|x_{SAT}|} \]  
\[ e_y = \frac{x_{SAT} \times x_{SUN}}{|x_{SAT} \times x_{SUN}|} \]
\[ e_x = -\frac{x_{\text{SAT}} \times (x_{\text{SAT}} \times x_{\text{SUN}})}{|x_{\text{SAT}} \times (x_{\text{SAT}} \times x_{\text{SUN}})|} \]  

(3)

If the coordinates of a point in the star-solid coordinate system are known to be:

\[ X = X_{\text{SAT}} + \left( e_x, e_y, e_z \right) \left( \begin{array}{c} x' \\ y' \\ z' \end{array} \right) \]  

(4)

2.2. Composition of the GPS system

An initial GPS satellite constellation is planned to consist of 24 satellites. These satellites are distributed in three orbits with an inclination of 63 degrees and almost circular. The difference between the ascending points of adjacent orbits is 120 degrees, eight satellites are evenly distributed in each orbit. After repeated studies and modifications. Finally, the satellite was distributed over six orbital planes, four satellites uniformly distributed in each orbit \([8-9]\). When the cutoff angle is 10 degrees, a maximum of 10 GPS satellites can be observed simultaneously. When the cutoff angle, at 5 degrees, up to 12 satellites can be observed simultaneously, the GPS satellite constellation consisted of 23 Block II and Block IIA satellites at the end of 2000, and five Block IIR satellites. In general, users can observe 6-8 satellite at the same time \([10]\). Geometric distribution of satellite position in the sky directly affects GPS positioning accuracy. Sometimes at some point on earth, there is a risk that the precise geodetic coordinates of the observation points will not be obtained, this time period is called "gap segment". But this time and place is rare, this can be well avoided in general geodesy, so it doesn't affect the positioning measurement.

2.3. Internet technology

With the continuous development of science and technology, the four technological revolutions have caused earth-shaking changes in human society. From the first technological revolution in the late 18th century to the electrification of productive forces and relations of production in the 19th century, to the comprehensive automation of productive forces and relations of production in the 1940s and 1950s, today's fourth technological revolution, represented by information technology, has emerged. The fourth technological revolution gave birth to the informatization of the mode of production and provided a new paradigm for the economic, political, cultural and even social development of the world today. Internet technology has three meanings in concept category: first, hardware level. Refers to a variety of data storage, processing and transmission equipment, mainly including host equipment and network communication equipment. Second, the software level. It is mainly for all kinds of software to retrieve, collect, apply, store, analyze and evaluate the data. Thirdly, at the application level, it mainly processes and applies all kinds of software to the information data, which provides the auxiliary function for the decision maker.

3. Experiments

3.1. Experimental subject

In recent years, the global construction accident disaster occurs frequently, the high building is subjected to the strong load pressure, the building structure bearing capacity reduces and so on force majeure factor, causes the human life safety to be threatened, in this background. This paper studies the deformation monitoring field of satellite navigation system and plays an important predictive role; With the rapid development of Internet technology and information technology, the maximum use of satellite navigation technology plays the most important role in the deformation monitoring of building structures, and it is an urgent scientific and technical problem to ensure a long-term monitoring environment.

3.2. Empirical method

Based on the definition of satellite navigation system, the components of satellite navigation system
and the definition of Internet technology, the deformation monitoring of a high-rise building is carried out in stages (continuous hours). The deformation monitoring data are fitted by the data curve of the first 9 hours. According to GPS theory, Internet technology theory analysis and practical analysis, the high-rise buildings in modern cities are in dense areas, which makes monitoring more difficult, and the monitoring of building deformation in the future needs more accurate positioning.

4. Discussion

4.1. Analysis of different monitoring techniques
In all fields of the world, the existence of deformation is very common, especially the unstable structures such as high-rise buildings, dams, reservoirs, etc., because of the interference of various external factors, the phenomenon of jitter occurs. If it exceeds the reasonable range of jitter, it will lead to unknown dangers and disasters, which will affect the safety of people's lives and property. With the continuous development and progress of the society, the construction of basic projects such as locks, dams and modern buildings has been accelerated, and to some extent, higher requirements have been put forward for structural and precise deformation monitoring of engineering. In addition, the continuous intensification of human activities to damage the environment, coupled with rainfall and geological tectonic movement resulting in frequent geological disasters. Timely and effective monitoring of landslide hidden slope deformation information will become an important guarantee to ensure the safety of people's lives. At present, the commonly used monitoring methods include traditional surveying and mapping level, theodolite, total station and 3D laser scanner. These methods usually have the defects of long monitoring period, no real-time performance, low automation and high cost. As shown in Table 1, the characteristics of different monitoring methods are compared. Therefore, in the field of deformation monitoring, the research of high precision, real-time and reliability monitoring system has become one of the hot spots. Global satellite navigation system has been used in various fields now, the technology is relatively mature, the technology of satellite navigation system will have an irreplaceable position in the field of deformation monitoring.

| Technical name             | Monitoring cycle | Operational complexity | precision | Cost (year)       |
|----------------------------|------------------|------------------------|-----------|-------------------|
| GNSS technology            | actual time      | full automation        | mm/cm     | Tens of thousands |
| Synthetic Aperture Radar   | One week or more | supermatic             | mm/cm     | Hundreds of thousands |
| Interferometry             |                  |                        |           |                   |
| total station              | Planned, non-    | manual operation       | millimetre| Tens of thousands |
|                            | real-time        |                        |           |                   |
| 3-d laser scanner          | Planned, non-    | manual operation       | mm/cm     | Hundreds of thousands |
|                            | real-time        |                        |           |                   |

4.2. Prediction of deformation monitoring for high-rise buildings
In order to make the deformation monitoring system better meet the needs of practical engineering cases, it is necessary to make effective prediction of monitoring buildings. This paper mainly uses curve fitting method to predict. The monitoring data of a monitoring point for 10 consecutive hours were selected (as shown in Table 2). The station center coordinates of the monitoring points during this period are (10.2 287, 1.2381, -4.1863), for the first nine hours. The fitting curve is obtained
(Fig.1, Fig.2, Fig.3).

**Table 2. 10 Hourly Monitoring Data Variables**

| time | Northern Deviation(mm) | Orient directional(mm) | Deformation in elevation direction(mm) |
|------|------------------------|------------------------|----------------------------------------|
| 1    | -0.25                  | -0.055                 | 1.288                                  |
| 2    | 0.023                  | -0.286                 | 1.056                                  |
| 3    | -0.01                  | -0.267                 | 1.363                                  |
| 4    | -0.22                  | -0.089                 | 1.663                                  |
| 5    | 0.24                   | -0.47                  | 1.380                                  |
| 6    | 0.502                  | 1.167                  | 1.942                                  |
| 7    | -0.322                 | -0.468                 | 1.941                                  |
| 8    | -0.53                  | 0.457                  | 1.853                                  |
| 9    | -1.14                  | -1.278                 | 3.654                                  |
| 10   | -0.96                  | -1.147                 | 2.479                                  |

![Northward displacement](image1)

**Figure 1. Northward displacement**

![Eastern displacement](image2)

**Figure 2. Eastern displacement**
On the basis of the above model, the shape variables in the north, east and upper directions of the 10th hour can be calculated as -1.0 mm, -1.2mm and 2.7 mm, respectively. The difference between the three directions is 0.02 mm, 0.06mm and 0.263 mm, respectively, which indicates that the proposed curve fitting model can meet the requirements of deformation monitoring and prediction in a short time. Along with the rapid development of information technology and science and technology, the deformation monitoring system has stronger requirements for faster response, higher precision and higher effectiveness. Based on GPS precision positioning technology, it can better meet the needs of deformation monitoring of high-rise buildings in China at present.

5. Conclusions
On the basis of the above model, the shape variables in the north, east and upper directions of the 10th hour can be calculated as -1.0 mm, -1.2mm and 2.7 mm, respectively. The difference between the three directions is 0.02 mm, 0.06mm and 0.263 mm, respectively, which indicates that the proposed curve fitting model can meet the requirements of deformation monitoring and prediction in a short time. Along with the rapid development of information technology and science and technology, the deformation monitoring system has stronger requirements for faster response, higher precision and higher effectiveness. Based on GPS precision positioning technology, it can better meet the needs of deformation monitoring of high-rise buildings in China at present.

Acknowledgements
Shaanxi Province Key R&D Plan Industrial Field (2021GY-101).

References
[1] Han H, Li X, Cao L, et al. Millimeter-Level Precision Deformation Monitoring Algorithms and Implementation of Beidou Satellite Navigation System. IOP Conference Series: Earth and Environmental Science, 2019, 376(1):012008 (6pp).
[2] Lang X, Li W, Zhang Y, et al. Accuracy detection of Satellite Technology in the Deformation Monitoring of Slope. IOP Conference Series: Earth and Environmental Science, 2020, 580(1):012068 (12pp).
[3] Doke R, Harada M, Miyaoka K. GNSS Observation and Monitoring of the Hakone Volcano and the 2015 Unrest. Journal of Disaster Research, 2018, 13(3):526-534.

[4] Yuwono B D, Prasetyo Y. Analysis Deformation Monitoring Techniques Using GNSS Survey and Terrestrial Survey (Case Study: Diponegoro University Dam, Semarang, Indonesia). IOP Conference Series: Earth and Environmental Science, 2019, 313(1):012045 (10pp).

[5] Suito H. Current Status of Postseismic Deformation Following the 2011 Tohoku-Oki Earthquake. Journal of Disaster Research, 2018, 13(3):503-510.

[6] B L A, B W M, B Z Z, et al. Integration of terrestrial laser scanning and soil sensors for deformation and hydrothermal monitoring of frost mounds - ScienceDirect. Measurement, 2019, 131:513-523.

[7] Sun J, Yang C, Guo S. [Lecture Notes in Electrical Engineering] China Satellite Navigation Conference (CSNC) 2018 Proceedings Volume 497 | Feasibility Study of Low Cost Receiver for Deformation Monitoring. 2018, 10.1007/978-981-13-0005-9(Chapter 11):129-138.

[8] Wu H, Dai Y, Wang C, et al. Identification and Forewarning of GNSS deformation Information Based on a Modified EWMA Control Chart. Measurement, 2020, 160(11):107854.

[9] X Sun, Ning Y, Yang D. Research on the Application of Deep Learning in Campus Security Monitoring System. Journal of Physics: Conference Series, 2021, 1744(4):042035 (6pp).

[10] Biondi R, Steiner A K, Kirchengast G, et al. Supporting the detection and monitoring of volcanic clouds: A promising new application of Global Navigation Satellite System radio occultation. Advances in Space Research, 2017, 60 (12): 2707-2722.