ANNOTATION

dissertation for the degree of Doctor of Philosophy (PhD)
on specialty 6D071100 - Geodesy
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"Development and improvement of methods of automated geodetic control of deformations of high-rise buildings"

Relevance of the topic. Nowadays cities and especially megacities are experiencing the so-called "construction boom". Intensive development of urban space is underway. At the same time, due to the increase in the cost of land plots, there is a tendency to build high-rise structures. In these conditions there is a need to observe deformation processes of these objects, taking into account that they are the most sensitive to changes in the environment.

At present the volume of construction of high-rise structures is constantly increasing. At the same time, China and the United Arab Emirates are recognized world leaders in erecting high-rise buildings. The tallest building in the world with a height of 828 meters - Burj Khalifa - was built in Dubai in 2010. Kingdom Tower with a height of 1000 meters is also under construction in Jeddah (Saudi Arabia)

High-rise buildings are among the most complex objects of construction, a number of basic decisions on their design are coordinated by international public organizations of engineers and architects - IABCE - ASCE and CIB.

The normative documents regulate the necessity of survey monitoring of the technical condition of various structures, especially when their operating conditions change. However, there are rather few studies on the control of high-rise structures using modern geodetic measurements associated with remote sensing technologies, in particular terrestrial laser scanning.

The prerequisites for solving the problem of determining the deformations of high-rise structures are largely laid in the current normative and methodological literature on the assessment of deformations of various engineering structures. In this regard, a significant contribution to the development of this direction of geodetic works was made by famous scientists: Chan Man Hung, A.V. Komissarova, E.M. Medvedeva, A.I. Naumenko, G.A. Shekhovtsov, R.V. Shultz and others.

The use of modern technologies of measurements and their processing in relation to the subject under consideration is reflected in the domestic studies of M.B. Nurpeisova, K.B. Rysbekov, A.A. Igilmanov, A.S. Chultukov and others.

Nowadays it is possible not only to perform control by several points, which can be used to judge the most important types of deformation (roll, bending, irregular settlement), but also on the basis of digital three-dimensional models of high-rise objects to evaluate the deformation process in a wide range of possible types of deformation (local tension-compression, shear and fracture, torsion, etc.), practically on its entire outer surface. In addition, the model approach allows us to consider the deformation process in a comprehensive way: the actual data can be used in software complexes to assess the stress-strain state, significantly improving the quality of solutions to ensure the safe functioning of a high-rise structure. It is also important to note a significant difference in the deformation of high-rise and low-rise

structures. If with respect to the latter, it was possible to trace the deformation process by the settlement of its foundation, then high-rise structures may show critical deformations when the foundation is immobile. The dissertation research is devoted to the solution of these topical issues and other related ones.

The aim of the research is to develop and substantiate the method of geodetic control of deformation processes of high-rise buildings, allowing to improve their safety during construction and operation.

The main idea of the work is to develop and validate an innovative method of monitoring high-rise buildings based on the use of available non-metric cameras with QR-coded targets to solve the tasks of monitoring various engineering structures, including high-rise buildings based on machine vision using an integrated GNSS system.

The main objectives of the study:

1. analysis of modern technologies and methods of geodetic monitoring of high-rise structures, regulatory requirements and principles of organization of automated monitoring systems.

2. Development of an integrated system of automated geodetic monitoring based on the principles of machine vision and satellite measurements. 3.

3. Simulation modeling and accuracy study of the automated system of geodetic monitoring of high-rise buildings.

Scientific provisions for defense

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1. integrated system of automated geodetic monitoring of deformation processes of high-rise buildings using digital camera systems and global navigation satellite systems (GNSS).

2. Methodology of processing the results of geodetic monitoring of deformation processes of high-rise buildings.

Scientific novelty

1. An integrated system of automatic geodetic monitoring and its simulation model have been developed, which allows to automatically determine relative displacements between structural elements of a high-rise building using machine vision with subsequent integration of the obtained results with GNSS observation data.

2. The methodology of processing the results of geodetic monitoring of high-rise buildings based on modern software packages (MatLab, Potomodler), which allows to model the structural elements of buildings and assess the accuracy of measurements, is proposed.

Main results of the research

1- Experimental measurements were made using a General Electric G100 digital camera to verify the theoretical considerations. The QR target was moved in the horizontal plane by small set points.

2. Three tests of measuring the QR target displacement at distances of 33 m, 25 m, and 17 m using the phase correlation algorithm were performed. The RMS error was 6.5 mm.

3. Modeling of the surveillance system for a typical building with a height of 90 m and 420 m was performed. The sensors are located at a distance of 30 m from each other.

4. Error ellipses for the sensor-target system and for the relative accuracies between sensors are presented. The vertical displacements, roll, bending and torsion of the building are described.

5. Verified the effectiveness of modeling for tall building integration of the surveillance system and GNSS. Measurement accuracies with and without additional GNSS observations are determined. RMS errors are presented for absolute and relative coordinates.

These results show the effectiveness and measurement accuracy of a non-metric camera system for monitoring movements in buildings.

The object of the research is a computer model of a high-rise building.

The subject of the research is the methodology of automated geodetic control of deformation processes of high-rise buildings based on the system of non-metric digital cameras and global navigation satellite systems (GNSS).

Methodological basis of scientific research

The methodological basis of scientific research includes analysis and generalization of scientific, technical and regulatory information, mathematical methods for experimental data processing and computer modeling. In the course of the study laboratory tests were conducted at the Kyiv National University of Civil Engineering and Architecture at the department of "Applied Geodesy".

Research Methods. To solve the set tasks, the system of digital cameras was investigated, the necessary parameters of the system were determined, theoretical calculations of output signals were carried out, testing and modeling of the system with GNSS support and without GNSS support was carried out.

Practical significance

The dissertation work has a practical orientation. It substantiates the application of machine vision system for geodetic monitoring of high-rise buildings. Methodological recommendations for the field and cameral stages of object surveying are formulated. In addition, models for two cases of monitoring without GNSS support for low-rise buildings and with GNSS support for high-rise buildings were developed.

The modeling results confirmed the conclusions about the system capabilities, especially in terms of taking into account GNSS data. The obtained results provided the necessary scientific basis for further development of the system, and the proposed monitoring method can be automated.

In this regard, the obtained results can be used by design and construction organizations in planning and carrying out works on monitoring the technical condition of high-rise buildings on the basis of automated technologies.

The theoretical and methodological provisions outlined in the paper can be implemented in the educational process when students study special disciplines of the training direction "Geospatial Digital Engineering".

Author's personal contribution:

- Analyzing the current state of study of the issue of geodetic monitoring of high-rise structures;

- setting the main tasks of the research;

- modeling of deformations of high-rise structures;

- development and approbation of automated algorithms to account for deformation processes of buildings;

- formulation of scientific provisions and main conclusions of the thesis.

Approbation of work

The main results of the research were obtained on the basis of modern monitoring system with software in the laboratory "Geomechanics and Geotechnology" of Engineering Center of Satpayev University within the framework of PCF BR21881939 "Development of resource-saving energy-generating technologies for mining and metallurgical complex and creation of innovative engineering center".

Key provisions and results of the dissertation work were presented and discussed at the following scientific and practical and international conferences: Proceedings of Satpayev readings innovative technologies - the key to successful solution of fundamental and applied problems in the ore and oil and gas sectors of the RK economy. Almaty - 2019, Proceedings of "XVII- International Congress of Surveyors" - Irkutsk: IrNITU 2019, Problems of subsoil development in the XXI century through the eyes of young people 2019 Moscow.

Reliability and validity of the results of the work is confirmed by the consistency of experimental data with theoretical studies using modern certified methods of data processing new modern automated technology.

Publications

The main scientific provisions and practical results of the thesis are published in 13 papers, including 2 articles - in the publications included in the list of leading peer-reviewed scientific journals; 1 article - in the publications included in the List approved by the Committee for Control in the field of education and science of the Ministry of Education and Science of the Republic of Kazakhstan; 4 articles in foreign journals and 6 articles at international conferences.

Scope and structure of the work

The text of the dissertation consists of an introduction, 3 chapters and conclusion, a list of used sources and appendices, set out on 99 pages of typewritten text and contains 46 figures, 14 tables, a list of literature of 67 titles, 2 appendices.

Conclusion

In this thesis work, a new approach to monitoring high-rise buildings using a GNSS-assisted non-metric digital camera system has been proposed. Verification of the accuracy of a single circuit of the non-metric camera system on a testbed confirmed that the required monitoring accuracy could be achieved. The proposed method of image pair offset determination based on phase correlation algorithm showed stable results in a series of in-situ experiments. Based on the experimental results, sufficient distances between the sensor and the target to ensure acceptable accuracy were studied and determined. Modeling of the non-metric camera system was conducted for two cases: without GNSS for low-rise buildings; non-metric

camera system with additional GNSS observations. The simulations showed the required accuracy for deformation monitoring in the case of available GNSS-assisted non-metric camera system. The results presented in this paper are mainly based on simulation studies. This provides a basis for further research on the use of non-metric cameras in real-world deformation monitoring of high-rise buildings.

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