Research on life cycle deformation monitoring system of Airport

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Abstract: In order to meet the rapid development and strategic needs of the national economy, a large number of airports are newly built, rebuilt and expanded every year in China. With the accelerating process of urbanization, the airport construction environment is getting worse and worse: the terrain is complex, the construction process is often accompanied by high excavation and deep filling of earthwork, and the high filling airport is often accompanied by the problems of foundation settlement and slope safety and stability. Therefore, it is very important to identify and monitor the existing or potential deformation of the airport and the deformation under the external environment such as earthquake.

1. Introduction

Aiming at the key and difficult points of the current expansion project of a domestic airport, this paper continuously observes and analyzes the deformed body based on remote sensing and sensor technology, and timely and effectively predicts the deformation development trend. In the stage of airport construction, it is planned to establish a monitoring reference network through sensor monitoring technology to realize the deformation monitoring of channel area and slope area; In the airport operation stage, it is proposed to use InSAR technology to realize the full range settlement monitoring and deformation analysis of the airport, and D-InSAR is proposed to realize the settlement monitoring and early warning in key areas of the airport [1]. At the same time, based on the massive monitoring data, the airport deformation trend analysis and early warning system within the airport is developed to realize the functions of airport deformation visualization, deformation dynamic monitoring, settlement trend analysis, hidden danger point identification and deformation early warning, so as to provide a reference basis for the prevention and control of high fill foundation disasters.

2. Life cycle deformation monitoring of Airport

In view of the key and difficult points of the current expansion project of the airport, the deformation body is continuously observed and analyzed based on remote sensing and sensor technology, and the deformation development trend is timely and effectively predicted. In the stage of airport construction, it is planned to establish a monitoring reference network through sensor monitoring technology to realize the deformation monitoring of channel area and slope area; In the airport operation stage, it is proposed to use InSAR technology to realize the whole range settlement monitoring and deformation analysis of the airport, and D-InSAR is proposed to realize settlement monitoring and early warning in key areas of the airport [1]. At the same time, based on the massive monitoring data, the airport deformation trend
analysis and early warning system is developed to realize the functions of airport deformation visualization, deformation dynamic monitoring, settlement trend analysis, hidden danger point identification and deformation early warning [2].

3. InSAR technology monitoring
InSAR (interferometric synthetic aperture radar) combines synthetic aperture radar imaging technology and Interferometry Technology to accurately measure the three-dimensional spatial position and small changes of a point on the surface by using the system parameters and imaging geometric relationship of the sensor. InSAR can be divided into three measurement modes: cross trajectory interferometry, along trajectory interferometry and repeated trajectory interferometry. The basic principle of InSAR repeated trajectory interferometry is as follows: firstly, two SAR complex images are obtained by observing the same ground object twice in parallel through two antennas; Then, using the geometric relationship between the target and the positions of the two antennas, the phase difference between the complex images is processed by interference to generate an interferogram; Finally, by analyzing the geometric relationship among flight platform, beam apparent direction and baseline, the surface elevation information can be obtained.

The so-called interferometry refers to the measurement technology that converts the interferometric phase into the height of ground objects after removing the flat ground effect, calculating the elevation ambiguity and unwrapping the phase of the interferometric phase map. The interference phase can be understood as the reflection waveform difference of the same ground object to the same wave band radar wave transmitted at two different positions, which is obtained by multiplying the phase complex conjugation of the two echo signals. The calculated interference phase contains the distance difference between radar and ground objects and the change information of scattering phase caused by the different transmission positions of two radar waves. Therefore, the distance information needs to be converted into terrain and deformation information in combination with radar position, attitude, baseline length and other data. One of the key steps often mentioned is interference phase unwrapping, that is, the process of restoring the winding phase that changes periodically between $-\pi$ ~ $\pi$ to the real phase [3].

4. D-InSAR technology monitoring
When the DEM is obtained by the common single antenna interference, the surface deformation is assumed to not occur in the time interval of the two scene images. If the surface deformation occurs during this period, the deformation can be obtained by eliminating the phase representing the elevation of the surface in the interference phase, which is the D-InSAR. D-InSAR is divided into three types according to different difference modes:

1) Two track method: two track method uses two scene repeated orbit image to interfere, then introduces the existing DEM data from the outside, simulates the terrain phase representing the surface elevation by DEM data, and then removes the deformation information from the interference phase.

2) Three track method: the three track method is to obtain three scene images in the research area, one of which is selected as the main image, and the other two images are used as the interference between the secondary image and the main image. The condition to be satisfied is that one of the two interferograms obtained spans the deformation time point, and the other is not across the deformation time point. The surface elevation is obtained by using the interference pairs that do not span the deformation time point, and the deformation information can be obtained by removing the interference map from another interference map crossing the deformation time point;

3) Four orbit method: two images are obtained before and after the time point of surface deformation for interference, and the interference graph is differentiated. The result is the surface deformation information.

In essence, the basic principles and ideas of the three kinds of difference interference methods are the same. In practice, because the terrain phase generated by the interference map contains errors, in order to avoid the errors in the results as much as possible, the most common method is the two track method. The simulation of terrain phase with the help of external DEM data with high reliability can not
only effectively reduce the error of differential interference, but also greatly simplify the data processing steps.

5. Analysis and early warning system of airport deformation trend based on monitoring data

At present, the standards for settlement stability control of civil aviation flight area can refer to the relevant provisions of industrial and local codes such as buildings and highways as follows:

(1) Code for measurement of building deformation (JGT / t8-97): whether the settlement enters the stable stage shall be determined by the relationship curve between settlement and time. For key observation and scientific research observation projects, if the settlement in each cycle of the last three cycles of observation is not greater than times the mean square error of measurement, it can be considered that it has entered the stable stage. For general observation projects, if the settlement speed is less than 0.01 ~ 0.04mm/d, it can be considered that it has entered the stable stage, and the specific value should be determined according to the compressibility of foundation soil in each area.

(2) Code for design of highway subgrade (jtgd30-2004): pavement paving shall be carried out after settlement is stable, and double standard control shall be adopted: that is, the calculated post construction settlement shall be less than the design allowable value, and the settlement observed for two consecutive months shall not exceed 5mm per month before unloading and excavating the road trough and starting pavement.

(3) In the study on treatment methods and settlement control standards of soft soil foundation of Shanghai airport, the settlement stability standard of soil foundation before pavement structure construction is that the monthly settlement rate is less than 8mm / month, that is, the daily settlement rate is less than 0.27mm/d.

The structure and use function of the airport are similar to that of the highway, and are quite different from that of general buildings. Therefore, the highway code can be used for reference. According to this requirement, it is roughly estimated that the daily average settlement should be less than 0.16mm/d, which is higher than the foundation settlement control standard of Shanghai Pudong airport.

Based on the sensor time series deformation analysis of the airport, the sensor data embedded in the airport pavement area and slope area are cleaned and analyzed to obtain the settlement duration change curve within the airport. The airport settlement is analyzed by analyzing the overall change trend of the settlement curve, the number and existing position of disturbance points.

Based on the post construction settlement calculation method, the measured settlement time curve of the project is fitted, and the settlement curve formula is established, so as to obtain the settlement observation data in the early stage of the project, so as to predict the development of settlement in the later stage and make dynamic prediction.

Based on the GIS platform, the airport design drawing is combined with the sensor monitoring data to realize the three-dimensional visual display of time series deformation and observe the airport deformation in real time [4-5].

Fig.1 D-InSAR data of an airport
6. Conclusion
Analysis and early warning system of airport deformation trend based on monitoring data. The basic idea of InSAR monitoring airport deformation is to use two or more remote sensing images covering the airport area before and after deformation for differential interference processing, and use the interference phase information in the differential interferogram to extract the areas or points whose deformation exceeds the set threshold. According to the location information of an airport in Yunnan, all points with strong coherence during imaging in the InSAR time series detection results within the airport are extracted, and the points are loaded on the average intensity map and satellite map of SAR image. The potential deformation points of the airport can be found intuitively and vividly from the figure. Based on big data analysis and expert experience, the threshold of airport deformation rate can be determined. If the threshold is exceeded, deformation early warning will be carried out. The system will automatically upload the location, range, deformation rate and early warning level of potential deformation points. Based on GIS, the development trend of deformation can be seen in real time to facilitate airport managers to timely and effectively understand the stability of high fill and prevent safety accidents caused by large-scale deformation.

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