IMAGE MODELING AND VISUAL MONITORING OF THE SLOPE NEAR HE DAM OF BAIHETAN HYDROPOWER STATION

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ABSTRACT

There are huge amounts of natural slopes and supported slopes on both sides near Baihetan hydropower station dam. Monitoring the surface dispalcement of slopes has has great significance under the influence of earthquake, water level fluctuation, geological structure, climate and weathering during the operating period of the power station. When it is analyzed that the slope is in the early stage of deformation, slope reinforcement measures can be taken before the slope deformation. This paper mainly studies and demonstrates the feasibility of image modeling and visual monitoring of slope. 2000 m2 slope was selected for the test in Baihetan power station adopting the method of target simulation. The geometry of the modeling body was built using the triangular network model outputs from ContextCaptureCenter, according to image data sources of different accuracy which were collected by drones with high-definition cameras. Finally, the models formed at different intervals were automatically compared and analyzed by means of clustering eigenvector space and changing mapping, and the purpose of monitoring slope surface displacement and deformation was achieved by image changes. The research results has significant reference meaning to the innovation of the monitoring and early warning mode of the slope near the dam.

1. PROJECT OVERVIEW

Baihetan Hydropower Station near the dam area contains natural slopes and supported slopes on both sides, and the number of slopes is huge. During the operation period of the power station after water storage and power generation, under the influence of earthquakes, water level fluctuations in the reservoir area, geological structure, climate, and weathering, it is of great significance to monitor the surface displacement of the slope. When the slope is analyzed, it is warned. Reinforcement measures can be taken before slope deformation and failure.

At present, the judgment of slope stability and deformation mainly uses the method of slope monitoring, and the data can be obtained through displacement monitoring pier, oblique hole, etc. for analysis. It has the following disadvantages:

(1) The operation risk of the data collection personnel is high;

(2) The data acquisition time is long and the acquisition speed is slow;

(3) There is a large demand for technical personnel;

(4) The data analysis cycle is long and the timeliness is poor;

(5) Equipment and facilities maintenance work is heavy.

At the same time, the data obtained from the limited measurement points to analyze a larger area may not be consistent with the actual situation on site. Engineering and technical personnel have a heavy task of measuring and analyzing data, and a large amount of digital information is not intuitive. This has a great constraint on the more realistic and intuitive slope stability analysis.

This paper mainly studies and demonstrates the feasibility of image modeling and visual monitoring of slopes. By using the actual site and target simulation methods, a slope test of approximately 2000m^2 (which is shown to be in the deformation stage by other monitoring data) was conducted at the Baihetan Hydropower Station for field tests. The drone is equipped with a high-definition camera to obtain a full coverage image of the slope surface area, and then according to different accuracy image data sources, the ContextCaptureCenter software is used to automatically output a triangular network model to restore the geometric shape of the modeling subject. Finally, the clustering feature vector space and the method of changing the mapping are used to automatically compare and analyze the models formed at different time points. The change of the image can be used to monitor the slope surface displacement and deformation.

2. PREPARATION OF TEST PROCESS

2.1 Test flow chart

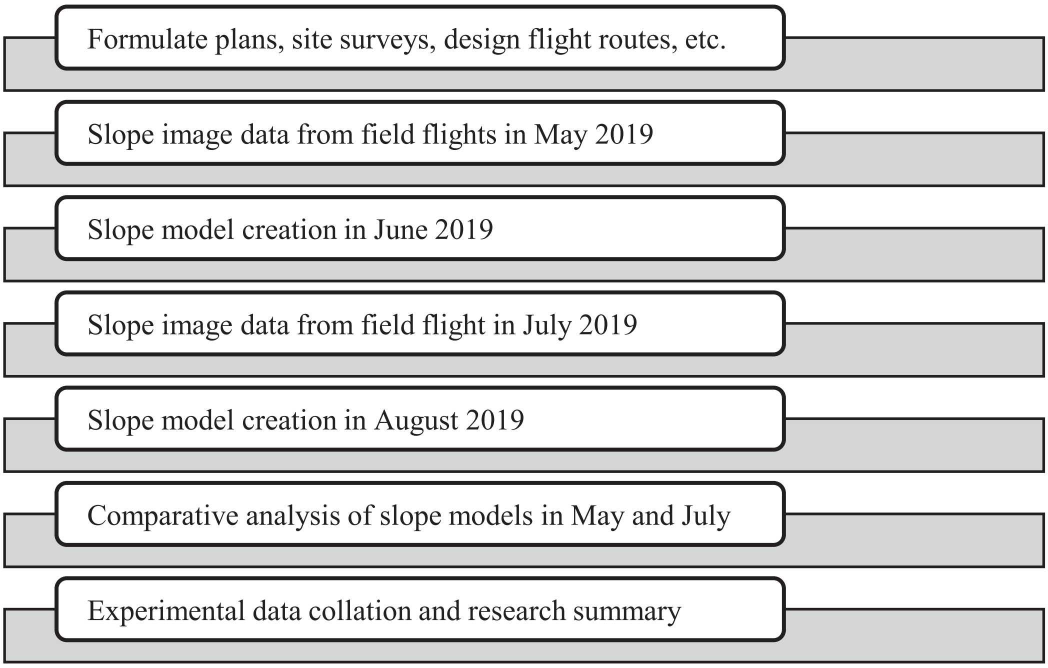

Figure 1 : Flow chart of the experimental process

2.2 Develop an experimental plan

Table 2 : Comparison of two experimental schemes

S.N.	Test method	Flight distance (accuracy)	Remark
1	Site actual	10m, 20m	Drone shooting angle is -10 °
2	Target simulation (9, two shapes and resolutions, 6 of which are moved horizontally to the right by 20mm overall during the experiment)	10m, 20m	

2.3 Image acquisition equipment

UAV aerial photography uses drones as aerial platforms, and uses airborne remote sensing equipment, such as high-resolution CCD digital cameras, light optical cameras, infrared scanners, laser scanners, magnetometers, etc. to obtain information, using computers The image information is processed and made into an image according to a certain accuracy requirement. The whole system has outstanding features in terms of design and optimal combination. It is a new application technology that integrates aerial photography, remote control, telemetry, video image microwave transmission, and computer image information processing. The Falcon8 multi-rotor drone was imported from Germany for this test image acquisition. The V-type 8-rotor drone is a “intelligent drone + artificial intelligence” drone that integrates professional detection aerial photography. Its basic structure includes: flight platform, flight navigation and control system (flight control system), ground monitoring system, mission equipment (sensor, camera), data transmission system, launch and recovery system, etc. It has the advantages of strong stability, no interference from magnetic fields, light and easy to carry, super high work efficiency, and extreme intelligent route planning.

2.4 Difficulties and Solutions

2.4.1 Due to the large undulation of the slope, the slope is distributed stepwise, and it is difficult to control the distance between the drone and the surface of the slope.

Solution : through the development of route planning software, increase the stepwise route planning and design functions. With this function, you only need to adjust the position of a single route to customize the route design.

2.4.2 Drones have high requirements for the operating environment, and harsh environmental factors will affect the take-off, landing, and navigation of drones.

Solution: Before entering the site for data acquisition by drone, observe and judge according to the weather forecast and site conditions, and stop flying operations when the wind exceeds 6 and rainy weather.

2.5 Field experiment standards and basis

Table 3 : Standards and specifications for experimental references

S. N.	Standard code	Canonical name
1	CH/Z3001-2010	Basic requirements for safe operation of drone aerial photography
2	CH/Z3002-2010	Technical requirements for drone camera system
3	CH/Z3004-2010	Low Altitude Digital Aerial Photogrammetry Field Code
4	GB/T18316-2008	Digital surveying and mapping results quality inspection and acceptance

3. EXPERIMENTAL RESEARCH PROCESSV

3.1 Site survey and target standard preparation

Before formulating the field flight plan, inspect the flight site and the area to be tested to determine the landing and landing points of the drone and the position of the drone operator. Observe whether there are buildings and other aerial obstructions in the surrounding area. If so, optimize the design of the flight plan. The test site situation is shown in Figure 4.

Because it is a feasibility study plan, there are uncertain factors about the feasibility of the plan and the analysis of slope displacement and deformation through the model. Therefore, 9 targets are fixed on the slope and numbered for easy identification. At the same time, in order to verify the accuracy of the results of the comparative analysis under the conditions of models with different accuracy (resolution), two targets are used. The differences are in the size and difficulty of recognition, as shown in Figure 5.

Figure 4 : Field experiment area

Figure 5 : Schematic of the target

3.2 Data Collection

3.2.1 *Route planning*

For the entire data acquisition process, the route planning software ASCTEC NAVIGATOR supporting Falcon8 multi-rotor drone is used to mark the area to be measured and design the route according to the shooting distance. In order to compare the effect of model analysis at different resolutions, when designing the route, two flight plans were designed by adjusting the relative positions of the route and the slope, so that the drones were 10m and 20m away from the slope. According to the current status of the slope, the drone load, that is, the camera adopts a shooting angle of -10 °, which is convenient for obtaining more details of the slope. Then adjust the altitude of the route through the ground station, the drone's heading (vertical to the slope), the overlap between waypoints (60% course overlap, 80% sideways overlap), flight speed (set to 4m / s) And other route parameters. The same route design was used for data acquisition in May and July 19th.

3.2.2 *Route flight*

In May and July 19, the drone automatically executed the planned route, and the data was continuously acquired at a speed of 10m / s. The route effect is shown in Figure 6.

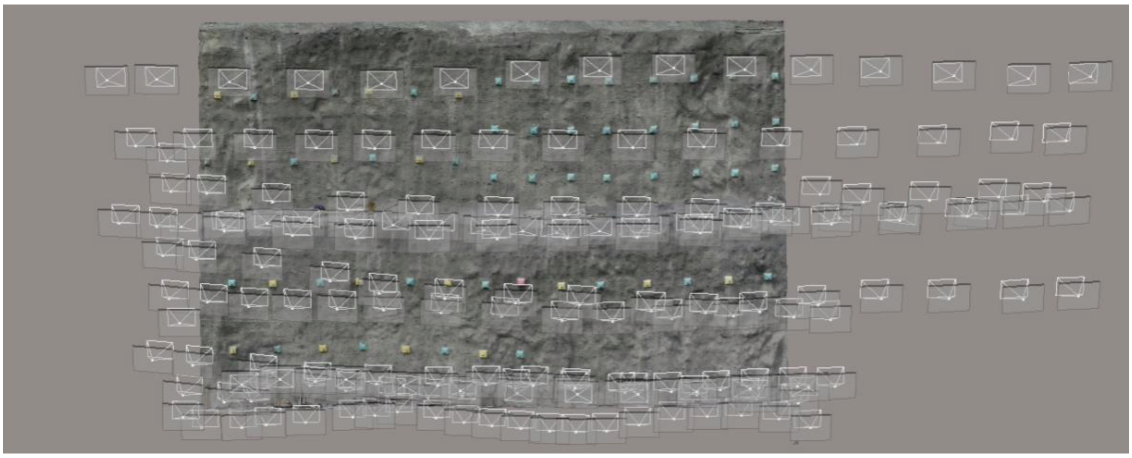

Figure 6 : Field experiment route effect

3.3 Data check

As an extremely important part of the entire research scheme, the quality of the data has a great impact on subsequent data processing and analysis.

Data inspection is mainly divided into two aspects: 1. the integrity of the data, and 2. the quality of the data.

(1) *Data integrity check* : The image data is not just photos, it also contains the pos information of the image given by the drone itself, that is, the waypoint position information of the drone and the attitude of the camera, etc., through ASCTEC NAVIGATOR The ground station software can observe the heading and sideways integrity of the image data, observe the continuity of the waypoint, and the information of the waypoint's height, pitch angle, yaw angle, and roll angle. As shown in Figure 7.

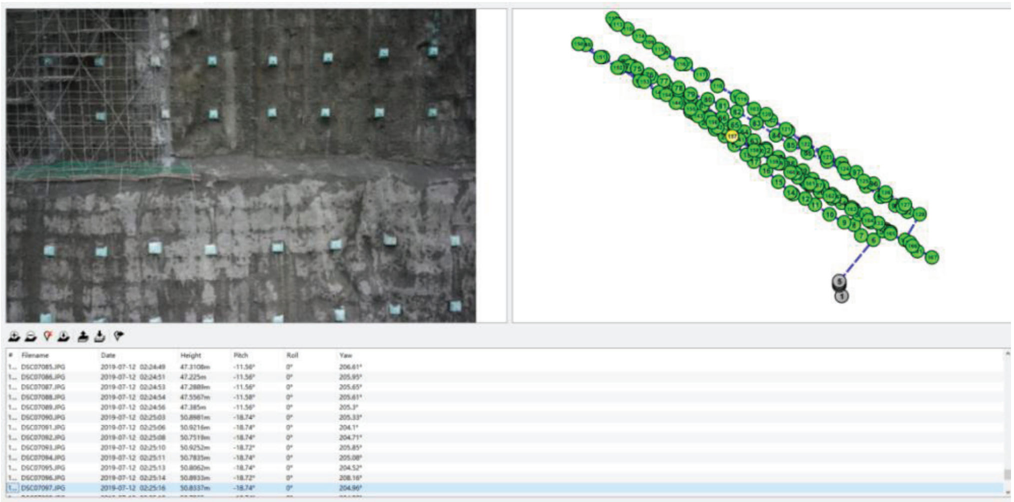

Figure 7 : Experimental data integrity check

(2) *Data quality check* : The quality can be checked according to the human visual perception. Select about 5% of the photos for inspection, observe the detailed parameters of the photos, and the color difference between multiple photos. Of course, there are The most important thing is to check if the photo has POS information.

4. MODEL CREATION

4.1 Modelling software principles

Based on the image data obtained previously, the ContextCaptureCenter modeling software is used to finely model the slope to be detected.

ContextCaptureCenter (CC) is a software solution that generates high-resolution 3D models from simple images or point clouds without any human intervention. ContextCaptureCenter is able to do this because it uses state-of-the-art photogrammetry, computer vision, and computational geometry algorithms to achieve industrial-grade quality requirements in terms of accuracy, scalability, efficiency, utilization, robustness, and interoperability.

4.2 Modeling results

4.2.1 *10m flight height model, see Figure 8*

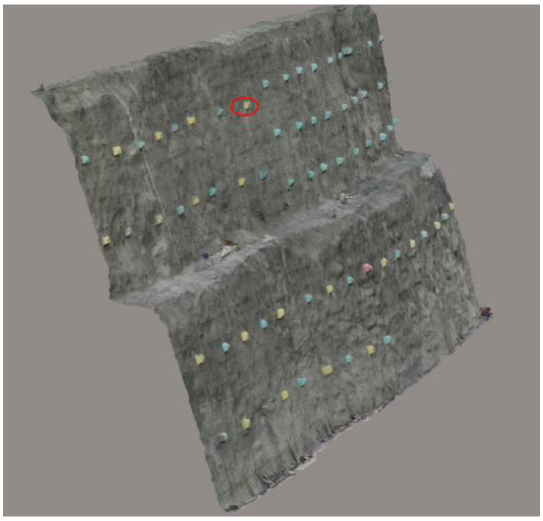

Figure 8 : 10-meter flight height model

4.2.2 *20 meters flight height model, see Figure 9.*

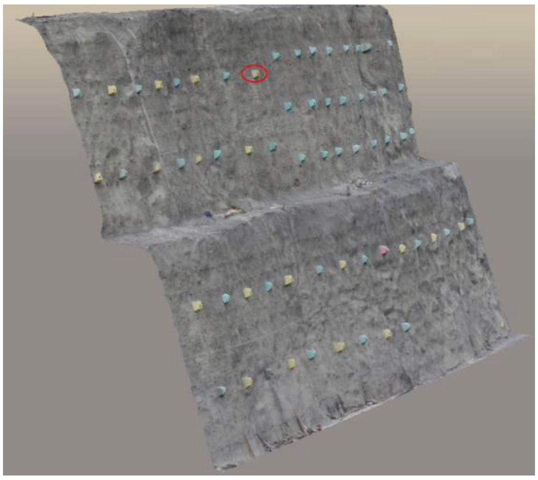

Figure 9 : 20-meter flying height model

4.2.3 *A detailed comparison of the generated models after 10m and 20m flight heights is shown in Figure 10.*

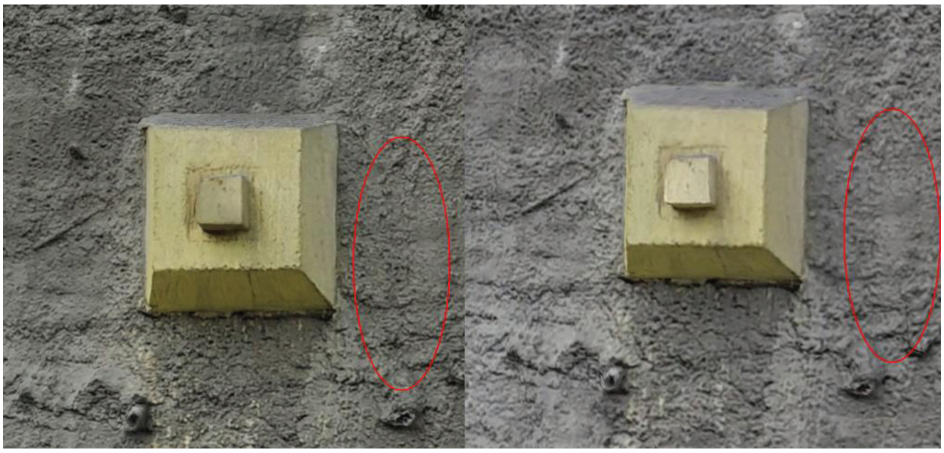

Figure 10 : Comparison of model details

It can be seen from FIG. 10 that the resolution of the generated model after a flight height of 10 meters is significantly higher than the generated model after a flight height of 20 meters. And through data collation and analysis, using a 10m data source, the resolution of the modeled image is less than 7mm.

5. MODEL COMPARISON AND IMAGE ANALYSIS

Area images acquired at different times are called multi-time images. Change detection involves analyzing two multi-time images and two multi-time models to find out any changes that may occur between two timestamps. This contrast detection anomaly method involves automatically analyzing changing data, that is, difference images, constructed using multi-time images. The difference image is a pixel-by-pixel subtraction of 2 images. Then, the principal component analysis (PCA) is used to extract feature vectors from the pixel blocks of the difference image. Then, a feature vector is constructed for each pixel in the difference image by projecting the neighborhood of the pixel onto the feature vector. The feature vector space is a collection of feature vectors of all pixels. Two clusters are given when clustering by the K-means algorithm-one represents pixels belonging to a changed class, and the other represents pixels belonging to an unchanged class . Each pixel will belong to any cluster, so a change map can be generated. The change graph is a black and white image, and specific changes can be obtained by analyzing the image.

(1) Obtain the test results according to the actual situation on the site. Align the two models in July and September. The difference between the images obtained by pixel comparison is shown in Figure 11.

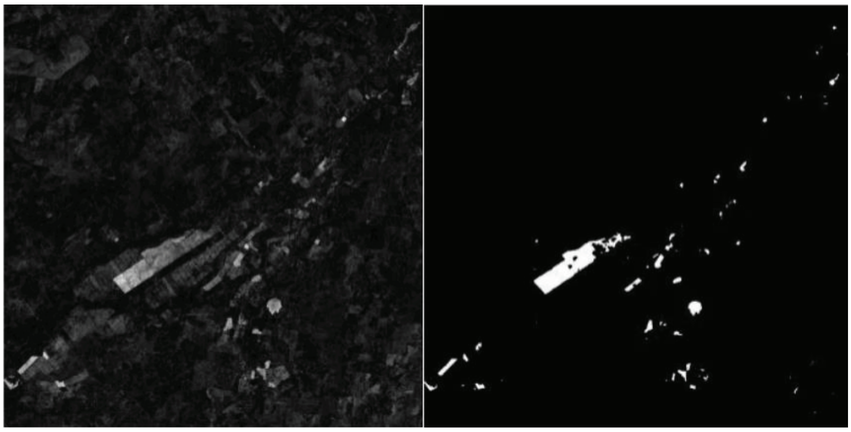

Figure 11 : The actual situation of the scene to obtain the black and white difference map

(2) The experimental results are obtained according to the target experiments.

First, align the two models at different periods, and compare the pixels to get the difference map of the image. The two models were shot at the same location at different times.

First, align the two models at different periods, and compare the pixels to get the difference map of the image. The two models were shot at the same location at different times. After comparing the models, we get the difference maps, as shown in Figures 12, 13, 14, 15, 16, 17, and 18:

Figure 12 : Analysis before and after target 1 moves

Figure 13 : Analysis before and after target 2 moves

Figure 14 : Analysis before and after target 3 moves

Figure 15 : Analysis before and after target 4 moves

Figure 16 : Analysis before and after target 5 moves

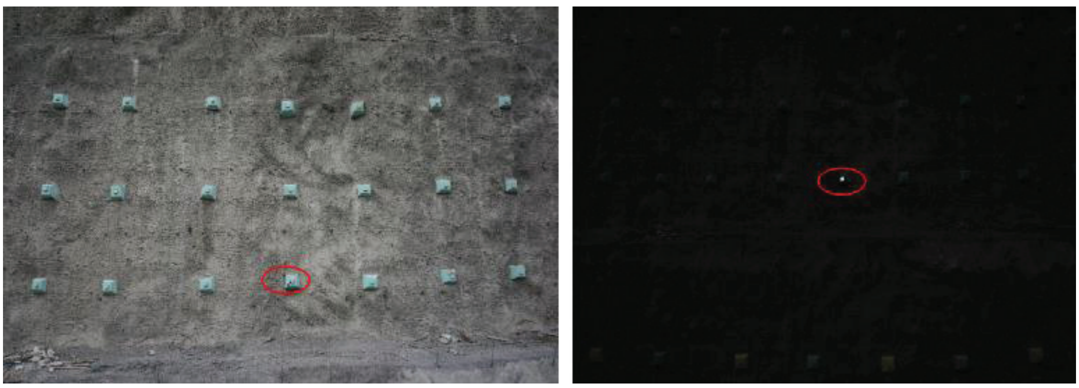

Figure 17 : Analysis before and after target 6 moves

Figure 18 : Overall effect of 6 target movements forming a difference map

6. TEST RESULTS

6.1 Analysis of experimental data

6.1.1 In the experimental area of about 2000m2, the monitoring center of Baihetan Hydropower Station already has the measuring point TPXCP-1-3, which is located at the elevation of 751 of the spillway exit slope. According to the data of the monitoring center, the maximum cumulative horizontal displacement of the TPXCP-1-3 measured points in May was 5.68mm, the maximum cumulative horizontal displacement in July was 7.01mm, and the difference between the cumulative horizontal displacement in July and May was about 1.33mm.

According to the actual situation of the site, a difference map (resolution 7mm) was obtained. The TPXCP-1-3 measurement point showed no horizontal displacement change. Because 1.33mm is less than 7mm, the white point of the difference map does not appear, which is a normal range. . The actual situation on the site shows that the white area shown in the difference map is the moving part of the on-site materials and equipment, and the experimental results are reasonable.

6.1.2 During the experiment, the six targets were shifted horizontally to the right by 20mm as a whole, and the horizontal displacement changes could be displayed in the difference diagrams, which achieved the expected results of the experiment.

6.2 Project Features

Image modeling and visual monitoring have the following characteristics:

(1) It can assist in demonstrating the reliability of data in existing monitoring methods.

(2) Reduce the operational risk of monitoring personnel.

(3) Real-time early warning of possible geological disasters.

(4) The collected data can be processed automatically, and the timeliness is improved.

(5) The amount of personnel input and equipment maintenance are small;

(6) The surface of the monitoring area is fully covered.

Table 19 : Comparison of artificial slope monitoring and image modeling monitoring

S.N.	Monitoring method	Base area	time	personnel	Equipment maintenance
1	Manual monitoring	10000m^2	2 days	5	Monitoring equipment, monitoring pier
2	Modeling, software analysis	10000m^2	real time	2	no

6.3 Project Overview

Fully demonstrated the feasibility of image modeling and visual monitoring of dam slope.

7. PROJECT OUTLOOK

(1). This project demonstrates that the monitoring method of image modeling can be used for deformation monitoring of slopes and key parts of hydropower stations.

(2). UAV shooting and three-model modeling can be applied to the initial data collection of structures in hydropower stations (submerged areas).

(3). It is possible to further study the field data automatic acquisition and the establishment of slope deformation early warning system, and gradually improve the modelling accuracy.

REFERENCES

[1] Yi-guo Chen, Ri-min Pan , Research and Implementation of UAV-based Image and GPS Data Acquisition System, Zhejiang Normal University, October 2011.

[2] Yi Zhou , Research on image modeling methods: [PhD thesis], Zhejiang University, October 2003.

[3] Hui Wang , Background Differential Image Processing: [Master Degree Thesis], Harbin University of Science and Technology, March 2005.