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The Monitoring Technology of the Scouring Process of Underwater Topography Based on Image Recognition

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Abstract: According to the characteristics of the scouring process of underwater topography by introducing the image processing and analyzing technology from the medical field, this study proposes a monitoring method for the scouring process of underwater topography which is based on the MATLAB image processing technology and used the red linear laser of 635 nm wavelength as auxiliary photo source. This method has the advantages of non-contacting measurement and real-time synchronous monitoring. At the same time, it puts forward the digital method of reproducing underwater topography on the basis of the MATLAB image recognition theory. Through practical application and error analysis in the research of the local scour of physical model, the results show that this monitoring system is very effective and can achieve the real-time and detailed monitoring and dynamic analysis of the scouring process of underwater topography.

Key words: Image recognition, underwater topography, scouring process, monitoring, laser

INTRODUCTION

The change of river regime and the local river bed deformation under the natural state or constructing projects is often determined through the experiment of physical model and the changes of underwater topography and river bed deformation need to be monitored in a lab. In order to know exactly the changes of river topography and riverbed erosion near buildings, especially the time-varying changes of local riverbed erosion, the real-time and dynamic measurement and analysis of underwater topography are absolutely necessary.

With the development of computer technology, image technology, optical technology, ultrasonic technology and laser technology, many instruments for the measurement of physical model topography have been developed at home and abroad, such as Photoelectric Reflecting Topographic Apparatus (Tang *et al*., 1995), Electrical Resistance Topographic Apparatus (Cai, 2004), Ultrasonic Topographic Surveying Meter (Wang and Jin, 2001) and Laser scanner Topographic Apparatus (Wang, 2007). The Electrical Resistance Topographic Apparatus and Photoelectric Reflecting Topographic Apparatus are relatively accurate and widely applied, but this kind of contact topographic apparatus can damage local topography and consequently influence the accuracy of measurement. The Ultrasonic Topographic Surveying Meter is non-contact and quick in measurement but not accurate enough, so it is usually applied in the outdoor field measurement. The Laser scanner Topographic Apparatus is accurate and quick in measurement but very expensive. According to the surveying features of the scouring process of underwater topography, the measurement apparatus should be not only noncontact, but also accurate and quick enough in measurement. As a result, based on the image recognition technique and using the linear laser as reference line, this study proposes a new monitoring and analyzing method of underwater topography and a surveying system which is quick and accurate enough without damaging the riverbed topography and can be easily applied in the monitoring of local scour of physical model. The practical application proves that this method is easy and feasible and can provide reference for the development of physical model measurement.

ESTABLISHMENT OF THE MONITORING SYSTEM

Basic ideas: Through the contour line of the underwater topography formed by the linear laser irradiation, the camera can capture the image of the moment. Consequently, with the help of image recognition

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Table 1: Laser parameters

Parameters	Wavelength (nm)	Output power (mW)	Supply voltage (V)	Operating current (mA)	Facula model
Value	635	5	DC 5.0	45	threadiness

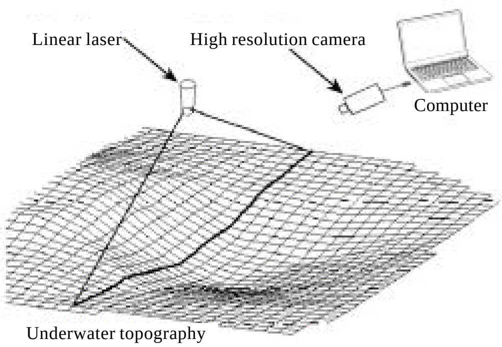

Fig. 1: Sketch map of the monitoring system

technique, the contour line of the underwater topography can be obtained at that time. After the linear irradiation of the whole underwater topography, a complete picture of the underwater topography is received. Real-time monitoring can thus be achieved through repetitively scanning by row (or column).The sketch map of monitoring system is shown in Fig. 1.

The main structure of the monitoring system: Compared with common light, laser is good in monochromaticity, coherence and directivity and high in brightness (Tan *et al*., 2010). Since laser is outstanding in directionality, convenient and easy to install and also stable and reliable which can greatly increase work efficiency, thus it is widely adopted in medical, military and measurement apparatus. In topographic measurement, 635 nm red laser is commonly used. In special cases, the 532 nm green laser can also be a choice. The width of the measurement range equals that of the laser line. The length of the measurement range is a function related to the stream flows. Experiments show that the length of measurement range should be twice the width of laser line. The main laser parameters are shown as Table 1.

The image recognition based on ATLAB: The image from the image acquisition module of the dynamic surveying system is in video form (usually AVI). Through recognition and processing of every frame of the surveying video, the reproduction of the underwater topography can be achieved (Lin *et al*., 2004). The pictures need to be enhanced after being captured, i.e., intentionally highlighting certain information put in the image while restraining or eliminating other information. The image enhancement technology can be divided into frequency-field method and space-field method according to different spaces in which the enhancement process is conducted.

Frequency-field method takes the image as two-dimensional signal and enhances it through two-dimensional Fourier transform with Low Pass Filtering Method or High Pass Filtering Method. Low Pass Filtering Method (by only allowing low-frequency signals to pass) can filter the noise in images while High Pass Filtering Method can enhance high frequency signals like edge signals and thus make the obscure images clear. In MATLAB, the function fir1( ) is used to design both Low Pass Filtering Method and High Pass Filtering Method.

However, the space-field method can calculate the grey level on the basis of frequency, i.e., amend image's conversion coefficient in certain transform domain. It is an indirect enhancement which can be achieved through concrete counting methods like point operation or neighborhood enhancement. Point operation refers to the revision and conversion of grey level and the amendment to histogram, in order to increase the level of imaging uniformity, enlarge the dynamic domain of the image and stretch the contrast. In MATLAB, the adjustment of grey level depends on function imadjust() while the equalization of histogram can use function histeq(). Neighborhood enhancement includes image smoothing and sharpening. Image smoothing technique is used to smooth the noise of the image which is basically applied in the evaluation of space-field's average value or mid-value and adopts the Low Pass Filtering Method. In MATLAB, it depends on the function smooth() to realize the smoothness of image. In contrast, the sharpening technique takes the High Pass Filtering Method which can reduce obscurity through enhancement of the high frequency elements, especially that of the vague edging part. But at the same time, it will enlarge the noise of the image. In MATLAB, the templates which correspond to the Robert gradient operator and Laplacian operator can be used to sharpen the image.

The contour line of the underwater topography formed by the linear laser, after being recognized by MATLAB, becomes a zonal group of dots. A relatively ideal contour line can be obtained after smoothing, filtering and enhancing. Proper enhancement of the original image will generate clearer image which can reflect its structural features in a rather concrete way and facilitate the reconstruction and display of underwater topography. The original recognized image and the proper enhancement image by MATLAB are shown in Fig. 2.

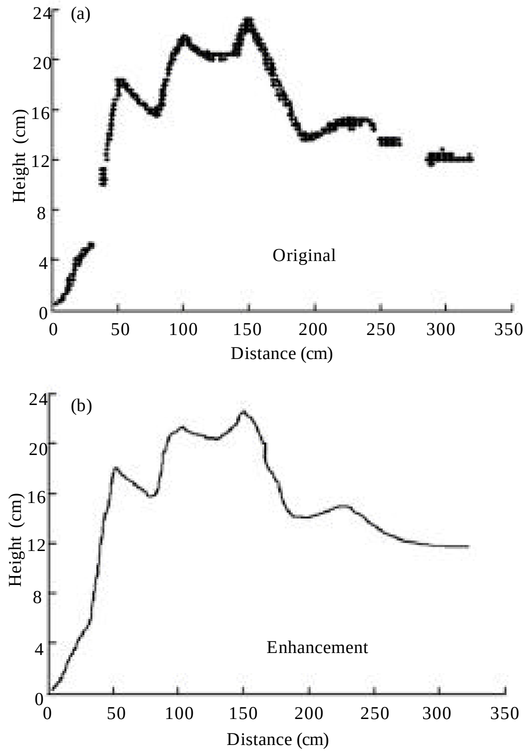

Fig. 2(a-b): Image comparison of original and enhancement

The digital reproduction of underwater topography: In actual application, the linear laser should irradiate the topography vertically in order to reduce the interference of water refraction to the image. The best angle in which the camera is installed should be the angle perpendicular to the laser's irradiation surface. However, in real situation, proper adjustment of the camera angle is indispensable for the complete shoot of underwater topographic contour line. Thus, it is necessary to analyze the systemic error caused by the deformation of image and changes of shooting angle. The pixel coordinates, as the result of image recognition, should be restored to actual ones. To solve the problems of image deformation and coordinate restoration, three or more reference points can be used for revision (Luo and Nie, 1999). After a large amount of experiments of the errors caused by different incident angle during the process of image acquisition, the error curve for analysis can be obtained. The MATLAB source code of digital reproduction of underwater topography is as follows:

```
mov=mmreader('Test.avi');fnum=mov;
 NumberOfFrames;
 for ii=1:fnum
  pix =read(mov,ii) ;
    for i = 1:size( pix,1 )
     for j = 1:size( pix,2)
       if pix( i,j,1) >=100
         rst = cat(1,rst,[i j]) ;
       end
     end
end
 x = rst( 1,:) ; y = rst( 2,: ) ;
 yy_loess = smooth( x,y,0. 1,'loess ') ;
 [xx,ind]= sort( x) ;
 new =[xx; ii* dist* ones( size( xx) ) ; yy_loess( ind)'];
         sf = cat( 2, sf,new) ;
end
minsfx =min( sf( 1,: ) ) ; maxsfx =max( sf( 1,: ) ) ;
minsfy =min( sf( 2,: ) ) ; maxsfy =max( sf( 2,: ) ) ;
[XI,YI]=meshgrid( minsfx: maxsfx,minsfy: maxsfy) ;
ZI = griddata( sf( 1,: ) , sf( 2,: ) , sf( 3,: ) ,XI,YI) ;
surf( XI,YI,ZI); Shading interp;
```

APPLICATION EXAMPLES

In order to prove the feasibility of the monitoring method proposed in this study, a series of application and confirmation are performed in model tests. Figure 3 shows the scouring topography which is reconstructed with the data collected in the actual monitoring of the scouring process of underwater topography in certain physical model at different moments with the system recommended in this study. Figure 4 shows the local scour of certain submerged pipe-pile dike physical model, the image of local scour of the topography near the projects and also the imitated topography constructed with the data collected by the monitoring system. The comparison of data shows that the monitoring data reflects the features of local transformation of the riverbed near the projects which eventually proves that this system has very high simulation accuracy.

The measurement accuracy of the system can be affected by the camera pixels. With same sharpness, the higher the pixel or resolution is, the better the camera can reflect the details of underwater topography. However, in actual application, it doesn't mean that higher the pixel or resolution means better performance. The quality of the lens and the performance of the photosensitive elements should also be taken into consideration. After all, the sharpness of the image's details collected should be ensured to increase the accuracy of image recognition.

In clear water or when the sediment concentration is lower, the visibility of the water is better and the monitoring accuracy of the system is higher. As the sediment concentration increases, the visibility of the water declines and the monitoring accuracy will also be affected. When the laser cannot reach the riverbed surface, the underwater topographic sensor can be used to capture the scouring process of certain feature points on the riverbed surface and help monitoring the whole scouring process of underwater

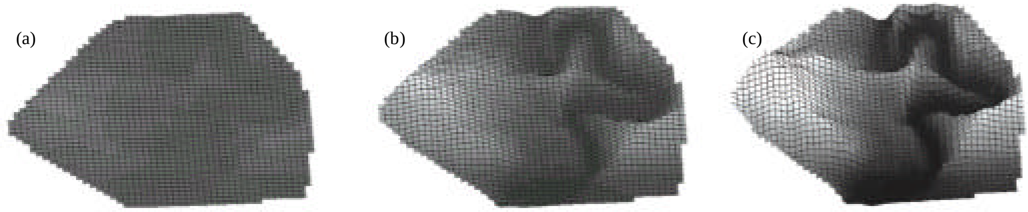

Fig. 3(a-c): Scouring process reconstructing of underwater topography at different moments (a) t_1 = 1h, (b) t_2 = 3h and (c) t_3 = 5h

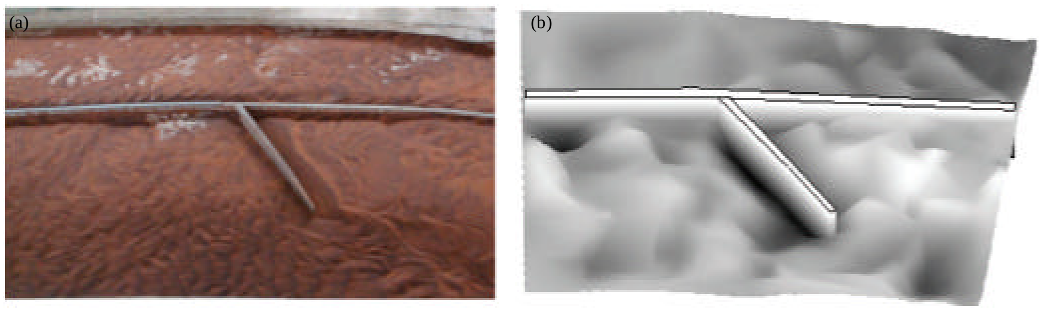

Fig. 4(a-b): Comparison of physical model picture and image by the monitoring system

topography. In the situation of high sediment concentration, this method will be restricted.

CONCLUSION

- It proves to be effective and high in practical value by obtaining contour line of underwater topography with the help of linear laser and introducing the processing and analyzing techniques of images from medical field
- Through collecting data with image acquisition method and processing data with image recognition technique, a lot of time can be saved along with the increase of efficiency. This approach is applicable for the monitoring of dynamic process
- The error of the monitoring system is mainly caused by the accuracy of the camera. Besides, the deformation during image collection, the water refraction and the radiation angle of linear laser also have some influence on the measurement accuracy
- In clear water or when the sediment concentration is lower, the monitoring accuracy of the system can be very high. In the situation of high sediment concentration, auxiliary methods can be adopted to acquire the changing process of feature points on the riverbed surface in order to complete the monitoring of the whole scouring process of underwater topography

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