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Research Status of Oil Well Casing Damage Image Recognition Technology

WANG Changjin[a],*; LI Yinpeng[a]; HA Mingda[a]

[a] Northeast Petroleum University at Qinhuangdao, Qinhuangdao, China.
* Corresponding author

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Abstract
Along with the production of the oil well, the casing damage has become more and more serious, which seriously affects the oil wells production, even resulting in the oil wells abandonment. The oil well casing damage usually occurs in the deep downhole place, and the imaging quality is generally low due to the complexity of downhole and the limitation of test equipment itself, it is difficult to identify the shape and parameter of the casing failure; therefore, how to accurately obtain the information of damaged parts becomes a big difficulty. Digital processing, image segmentation and edge tracing are carried out for the casing image by using image processing techniques. The physical dimension of the material object in the image is obtained by applying the image-forming principle, achieving the quantitative interpretation to the surface condition inside of the casing. The image recognition technology not only can quickly find the damaged parts but also can give the corresponding information for the damaged casing. In this paper, the image recognition technology of casing damages introduced.

Key words: Casing; Image recognition; Damage; Filtering

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INTRODUCTION
The oil well casing deformation, dislocation and corrosion perforation caused by corrosion, stress, wear and other factors have been getting worse, seriously affecting the oil wells production. At present, methods used for detecting the oil well casing mainly include: impression method, borehole diameter method, ultra-sonic detection, 40 arms, X-Y, 8 arms, multi-arm borehole diameter testing technology, and visible light downhole video logging system and so on, which have their own advantages and disadvantages. Among them, the visible light downhole video logging system directly scans the shaft and the internal wall of the casing pipe by using downhole CCD camera, while it displays and records images of the shaft and the internal wall of the casing pipe by using the ground instrument, what it sees is what it gets, from which you can directly get the condition of downhole casing. But, its disadvantage is that it is greatly limited by the visibility of the well fluid, whose imaging quality affects the feature recognition of the casing damage[1]. The image obtained by the downhole video is the 2D image, to explain the 3D object with 2D image still exist many difficulties. It observes and determines the damage through the artificial image, which exists leak detection, inaccurate information and other shortcomings, which limit the application of the visible light downhole video logging system in the casing damage detection. However, the image recognition technology just use the image processing techniques to carry out the digital processing, image segmentation and edge tracing for the casing image. In addition, it adopts the image-forming principle to obtain the physical dimension of the material object, thus achieving the quantitative interpretation to the surface condition inside of the casing, which promotes the application of the visible light downhole video logging system in the casing damage detection.

1. CAMERA SYSTEM

Optical imaging logging technology is a hot research topic and development direction of modern well logging technology. In the 1940s, some people obtained the downhole image technology with camera, but limited by the technology at the time, only black-and-white still image would be obtained, in addition, the size of the logging instrument was relatively large, with a maximum logging depth of 1,000 feet.

In the 1990s, the optical technology was greatly developed, in addition, a compound photoelectric logging cable of optical fiber and cable (Photo Electric Logging Cable) born. With smaller cable diameter, this kind of cable had greatly improved the speed of data transmission, which thus had been applied widely in the petroleum, natural gas and other productions and had greatly enhanced the performance of the downhole television. America DHV Oil Logging Company developed the Hawk-Eye which was a highly integrated downhole image logging system, using the same downhole electronic components as the optical-fiber downhole television, but using the different interchangeable electronics rack for the image processing. Because it could transmit downhole images in any standard cables and cords and the achievement of its equipment operation depended on the ordinary electric system, this determines it could be applied in the global scope. The Hawk-Eye is ideal to solve the mechanical damage problems for a single stationary object observed and analyzed.

Camera system is designed to video the downhole casing status, usually composed of two parts, including the underground camera system and the ground receiving and processing system. It videos the internal wall of the casing pipe with the camera. Under the lighting of rear tungsten lamp of the downhole instrument, the electronic circuit converts the image signal into the pulse frequency signal, and the single-core coaxial cable or the multi-core cable transmits the image to the ground receiver which amplifies and decodes the image to produce the same image as that gained by the downhole video and send one way of the image signal to VCRs and plotters for record and real-time printing, and send the other way of image signal to viewers for review. During the process of downhole imaging, the light projected by the camera is required to be even and camera lens shall not be polluted by oil stain, in order to obtain high video quality.

2. 2D IMAGE PROCESSING AND 3D IMAGE RECONSTRUCTION TECHNIQUE

For filming, the camera moves on the axis of the casing pipe, pictures filmed are annulus, and the first step of image processing is to recuperate the annulus image filmed in the casing pipe with camera into cylindrical or rectangular image ease of identification. Based on the camera structure principle, 2D images of the plane miniature inside of the real casing pipe can be reconstructed by combining the camera's imaging principle with the definition of the magnification. But because there are always sags and crests inside of the casing pipe with defects, it is necessary to study its 3D situation, in order to identify defects inside of the casing pipe and to predict its service life. The method is to convert the reconstructed rectangular images into gray-scale images firstly, and then get any point (x, y) from the rectangular gray-scale images to get the only corresponding gray-scale value to set up a gray-scale function[3]. By sampling and getting some points from the rectangular gray-scale images, use Photoshop to measure the corresponding gray-scale value, or use Matlab software package to draw the line drawing of gray-scale value and other values, to simulate the gray-scale function $v = f(x, y)$. Concrete practices are as follows:

(a) Convert the reconstructed rectangular images into gray-scale images.

(b) Subdivide the squared grid on rectangular gray-scale images.

Subdivide the rectangle in length of $2\pi KR$ and height of H into $n\times m$ small squares, and its step length d is the edge length of small squares, namely $d = 2\pi KR/n = H/m$, the node coordinate (x_i, x_j) is:

$$x_i = i_d\,,$$
$$y_j = j_d\,.$$

Among where, $i = 0, 1, 2, ..., n$; $j = 0, 1, 2, …, m$.

(c) Find the corresponding gray-scale value $v_{i,j} = f(x_i, x_j)$ of each node (x_i, y_j) by using Photoshop with a combination of the programming, or make the line drawing of gray-scale value and other values with Matlab software package.

3D reconstruction can be carried out for the 2D casing image by using the character of the gray-scale function, and the distribution of casing damage and types of defects are identified preliminarily by analyzing and studying the gray-scale value matrix, providing the basis for predicting the service life of the casing pipe, enable to classify the defects and predict and analyze the service life of the casing pipe.

3. FILTERING DE-NOISING OF DAMAGE IMAGE

Because the casing damage of oil well in the image boundary captured isn't very obvious, relatively large noise and multi-source fuzziness exist in the image, but noise of similar frequency always exists in the edge points after the image is processed by using traditional method. Meanwhile, the traditional edge operator is sensitive to the direction during searching, the edge extraction is carried out only on a scale, therefore, it is difficult to distinguish the small structural silhouette and big edge structure in the image, and it is hard to obtain a satisfactory result for the restoration of the degraded images, affecting the subsequent digitized quantitative interpretation of oil well casing damage image. In the literature III, the mathematical morphology is applied in the image processing, which has a unique advantage when describing the form and structure of an object in an image for it isn't sensitive to the edge direction and can effectively suppress noise to a large extent. In general, the common noises existing in the image processing technology of casing damage include[5]:

(a) Additive Noise

The additive noise isn't related to the image signal strength, such as the "channel noise" introduced during image transmission, and the noise incurred when the television camera scan images and so forth.

(b) Multiplicative Noise

The multiplicative noise is related to the image signal, which often changes as the image signal strength varies, such as the noise incurred in the process of flying-spot scanning, and the noise incurred when a television scans a grating and film grain and so forth.

(c) Quantization Noise

The quantization noise is the main noise source of the digital image, whose size shows the difference between the digital image and the original image.

(d) Salt-and-Pepper Noise

The salt-and-pepper noise is the noise caused by the image incision, such as the white spot noise in the black-and-white image, and the black spot noise in the white image; And the converter noise caused by the image inversing transformation within the error introduced from the transform domain and so forth.

At present, the de-noising method for the downhole television casing damage images mainly includes the median filtering and traditional mathematical morphological filtering and so on, which focus on the downhole television casing damage images obtained under the condition of low light and low contrast, but neglecting the detail signal, losing the detail information of the image edge, resulting in blurred images. And the traditional morphological filter only uses a structural element (shape or circular), which, effectively filters out the impulse noise in the image, but in the meantime, obscures many details of the image and other defects exist. Omnibearing morphological structure element is introduced based on the traditional mathematical morphological filtering, and an omnibearing adaptive weighted morphological filtering de-noising algorithm is put forward with the weighted array of the adaptive morphological algorithm, to carry out the de-noising pretreatment for the oil and gas well casing damage image obtained under the condition of low light, which can effectively remove the image noise, thus improving the accuracy of the digitized quantification interpretation during the image post process.

4. IMAGE SEGMENTATION AND EDGE DETECTION

The image segmentation extracts significant features section in the image (such as an object in the image edge), providing a base for the further image recognition, analysis and understanding. In the quantitative interpretation of downhole television image, by selecting an appropriate threshold value, the object region and the background region can be segmented in the image by using the binarization algorithm to carry out the segmentation process for the corresponding image, so as to obtain the corresponding binary image. In addition, some isolated points or sharp points exist in the image edge, which will affect the post edge tracking, therefore, the treatment to remove the isolated points and sharp points shall be carried out in the image. The key point of image segmentation is to determine the edge of casing defects in the image, the most basic features of the image. The intuitive explanation of the image edge is the one appeared on the border between two regions which have fully different gray-scale orders. The edge indicates the end of a region and the beginning of another region. Therefore, the image edge contains valuable target edge information, which can be used for the image analysis and the target recognition. In order to carry out a prompt and accurate quantitative interpretation of the downhole television image, a proven and effective edge tracking algorithm must be adopted to track the target border, recording the searched border point coordinates to form a point array which composes the image edge curve(such as the inner wall of the casing pipe and so forth.). To detect the image edge or to extract the image contour line from the image is the most basic operation before measuring the geometrical features of the image[2].

The traditional edge search methods is to complete the detection of the image edge normally by convolving its template with the image with the help of the airspace differential operator, such as Roberts operator, Laplasse (4-neighborhood), Laplasse (8-neighborhood), and extraction operator at the lower right edge, etc. In this paper, 8-neighborhood search algorithm is introduced, which can track the edge of an image quickly and accurately. In the image, supposed the current point (x, y) is an edge point of an object, the next edge point must be within the 8 neighborhood of (x, y).The representation of the coordinate of 8 pixel position within this neighborhood and the coded representation are as shown in Figure 1. The criteria for determining the starting position of the 8 neighborhood search is as follows: supposed the location coding of the current point (x, y) in the previous edge point within the 8 neighborhood is m, the code of the current point (x, y) is the location of m, while the location gained by turning 2 pixels clockwise is the starting location of the next edge point for searching. Similarly, examine 8-neighborhood pixels counterclockwise in turns beginning from the starting location determined according to the above method, when the phenomenon that the gray-scale value is equal to the target value appears for the first time, the pixel point herein is the next edge point as required.

(*x*-1, *y*-1)	(*x*-1, *y*)	(*x*-1, *y*+1)
(*x*, *y*-1)	(*x*, *y*)	(*x*, *y*+1)
(*x*+1, *y*-1)	(*x*+1, *y*)	(*x*+1, *y*+1)

Coordinate Representation A

7	6	5
0	(*x*, *y*)	4
1	2	3

Coded Representation B

Figure 1
18 Location of Neighborhood

In reality, the noise and edge pixels are high-frequency signals, and the gray-scale value changes severely, therefore, the noise is strengthened while using the edge search algorithm to detect the edge[4]. The oil and gas well casing damage image edge search algorithm with omni-directional multi-scale morphology and the omnibearing structural element can extract the image edge in different directions, so as to better ensure the integrity of the image information; the multi-scale structural element can extract edges of different sizes, conducive to extracting the detail information and keeping the overall edge contour of the image[5]. Aimed at the characteristics of casing damage image, the edge search algorithm of omni-directional multi-scale morphology edge search algorithm is adopted to search the edge contour of the image and thus to gain the coordinate of the image edge, recording the searched border point coordinates to form a point array which composes the image edge curve (such as the inner wall of the casing pipe and so forht), namely the curve of casing pipes' inner diameter in the searched oil and gas well casing damage image[6].

5. QUANTITATIVE INTERPRETATION OF DOWNHOLE TELEVISION IMAGE

The combination of the shape description and the dimensional measurement serving as a basis to distinguish different objects plays an important role in machine vision systems after the objects are segmented out from the images. The physical dimension of parameters is obtained, such as the diameter of casing in the image, by tracking the image edge. According to the corresponding relation between the image and the real object, the physical dimension of the real object in the television image is obtained by using the image-forming principle, so as to achieve the purpose of quantitative interpretation.

CONCLUSION

The camera lowers into the downhole to take images, but directly imaging on the ground, what it sees is what it gets, from which, one can intuitively understands the condition of downhole casing pipe. However, it is greatly restricted by the visibility of the well fluid, whose imaging quality affects the feature recognition of the casing damage. The development of the image processing technology can return the 3D spatial form of casing pipe into the 2D image of casing damage, and the shape of the casing damage can be obtained more precisely by means of image filtering and de-noising techniques and image edge detection and so on, providing parameters for the quantitative interpretation of images.

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