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Intelligent analysis method of automatic welding quality based on X-ray imaging[1]

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Abstract. In the oil engineering construction and operation maintenance project, welding and nondestructive testing are the key construction processes. The timeliness and accuracy of welding quality analysis are important guarantees for the quality of petroleum engineering construction. Most of the petroleum engineering work environment is very complex. The welding quality of conventional detection technology has been unable to meet the demand, therefore, the automatic welding quality analysis based on X-ray imaging has become the main research technique at home and abroad. Under this background, in this paper, the welding quality analysis technology and the research status of X-ray image acquisition technology in China and abroad were analyzed; the principles of X-ray welding and the key technologies of visual inspection were analyzed; evaluation index was proposed for X ray imaging based on the welding quality; wireless transmission network based on regression model of welding was used, quality evaluation was optimized; through simulation experiment, its accuracy and feasibility were analyzed. This research has made certain contributions to the intelligent analysis method of automatic welding quality based on X-ray imaging.

Key words. Petroleum engineering, X-ray imaging, automatic welding, quality analysis.

1. Introduction

The total amount of petroleum resources in our country is insufficient, and the time and space distribution is uneven, besides, the oil field resource combination is not coordinated. With the development of oil field infrastructure and the increasing scale of oil and gas transportation system, long distance oil pipeline in China occupies an increasingly large proportion of oil and gas transportation. This has played an important role in China's national economic development and national strategic security reserves. The method of weld quality analysis based on X-ray imaging is of great value to the construction of petroleum engineering, especially for the welding quality inspection of long-distance oil pipeline. This is the most widely used method

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in the present stage of the weld quality inspection [1]. The intelligent analysis of weld quality based on X ray imaging is of great significance to ensure the quality of welded components.

A method for automatic detection of weld defects using defect tracking technique is proposed by Shao. This method uses the improved Hof transform to avoid the false defects caused by more noises, so as to ensure the accuracy of the welding defect detection. Vilar proposed a method to classify the defects of X-ray image automatically. This method can reduce the noise and enhance contrast to deal with the image of welding defects. Using the threshold selection, label technique and feature extraction method, it splits the welding defects [2]. After getting all the characteristic parameters, input it to the artificial neural network for processing (Artificial Neural Networks, ANNs), so as to realize the identification of defects. In order to get the best performance of the artificial neural network, the proposed method has been improved by using a variety of different methods to improve the neural network. In the input layer, the principal component analysis technique is used to reduce the number of feature variables. When dealing with the image of welding defects, Wang uses the three steps of image preprocessing, feature extraction and welding defects classification [3]. In the defect segmentation of image preprocessing, the two methods are proposed, which are background elimination method and histogram thresholding method. In the feature extraction step, a series of information parameters are extracted to describe the shape of welding defects. And in the third step, detect the defects of the welding classification. This step uses the fuzzy k- nearest neighbor algorithm and MLP neural network to send these two kinds of technology. Experiments show that, for the welding defects classification, the treatment effect of these two kinds of technology is excellent, reaching more than 90 % of the correct rate of judgment [4]. Du used the mean filter to do noise reduction processing for X-ray weld seam image, and achieved good results. Guo Dong analyzed the factors that affect the image quality of the weld, and put forward the application of computer aided image processing technology in the detection of weld radiographic. On this basis, the automatic recognition system of the weld negative image defect is developed. Based on the GB3323-87 standard, the system can assess the detected defects [5]. Zhang Quan proposed a digital image processing method based on the TV camera, and developed a corresponding image processing system and processing methods [6]. By using the method of gray level analysis, Wang Gang has carried out a series of noise reduction processing to the image, and proposed an S-T nonlinear gray image transformation method which can significantly improve the image sharpness and contrast. On this basis, the gray gradient method is used to extract the weld defects. This method can effectively enhance the effect of defects in the weld, but the contrast is not high, and the defect information will be lost [7]. X-ray digital imaging detection can be understood as direct digital imaging. In this method, the intensity of the radiographic image is converted to the visible light image in real time, and the test results are evaluated. For the inspection and evaluation of the weld quality of long distance oil pipeline with strong specificity and application limitation, the applicability of the present research is insufficient, so it is difficult to achieve the weld of pipeline inspection of complex geological environment under the cross region remote. At the same time, it also lacks the evaluation method and system which is suitable for the objective condition.

2. State of the art

2.1. Status of X-ray image acquisition research

At present, the X-ray detectors used in the electronic industry are basically foreign products. Among them, the most typical representative is the flat panel detector P3H271 which appeared in the end of 1990s. The flat plate type X-ray imaging detector uses two methods to convert X-ray photon conversion: direct and indirect methods. The structure of these two ways is different. The direct way uses a photoelectric conductor to convert the X-ray into electric charge. In the indirect mode, the photoelectric diode is used to convert the visible light photons into electric charge [8]. Compared with the direct method, the indirect method has more than one layer of the scintillation to convert the incident X-ray photons into visible light. In the detection of electronic industry, the commonly used methods of X-ray imaging data acquisition are mainly divided into film imaging and non-film imaging. Film imaging has the longest history, but its biggest disadvantage is that it cannot be detected and evaluated in real time, and the result is not suitable for long-term preservation. Non film imaging replaces film imaging with X-ray sensitive devices, which can be simulated images or digital images. This imaging technology can be real-time detection and evaluation. With the development of image processing technology, the technology has been widely used [9]. In 1950s, researches on X-ray image intensifier gained rapid development. The basic principle of the X-ray imaging device is electronic vacuum tube approach. Although it has the advantages of low price, fast imaging, its disadvantages are also obvious. For example, it can withstand a small range of X-ray energy, as well as a small area of visible light image and so on. In order to better collect data, in the end of 1990s, the X-ray digital radiography detection technology based on flat panel detector appeared, and began to be applied in the field of industrial radiographic testing. In order to improve the higher spatial resolution, the linear array detector appeared. This is a digital imaging device. A new type of X-ray detecting unit is arranged in an array, and the array is directly connected with the large scale integrated circuit to complete the whole process of ray receiving, photoelectric conversion, and digitalization. This direct conversion method reduces the distance of signal transmission, and reduces the noise generated during the transformation process. Using the corresponding filter circuit, we can obtain the image of low noise and high sensitivity. In wireless sensor networks, one of the major research challenges is to save severely limited energy resources and effectively extend the life cycle of the network [10]. The energy consumption of a sensor node can be divided into three parts: sensing loss, data processing loss, and transmission consumption. According to the survey of N. Kimura and S. Latifi, each sensor node has about 80 % of the energy loss for data transmission. Therefore, reducing the size of the data will reduce the transmission consumption. In order to realize the communication connection fault tolerance, the sensor node uses the redundant deployment way. Wireless sensor networks naturally show the high redundancy of temporal spatial sampling. Sampling redundant attributes can reduce the data flow in the network, which can reduce the energy consumption. The following picture is the scene of oil engineering.

Fig. 1. Oil engineering site

3. Methodology

The process of automatic welding quality analysis for X-ray imaging is shown Fig. 2

3.1. Multivariate linear regression models

Based on the simple linear regression model, we need to further explore the more complex multivariate situation. In wireless sensor networks, sensor nodes can monitor multiple variables. In addition, multivariate correlations are usually strong. Correlation is the data collected from one or more attributes of each sensor node at a given time. This is the nature of the observed physical phenomena. Simple linear regression models are able to study correlations, but it cannot study the multivari-

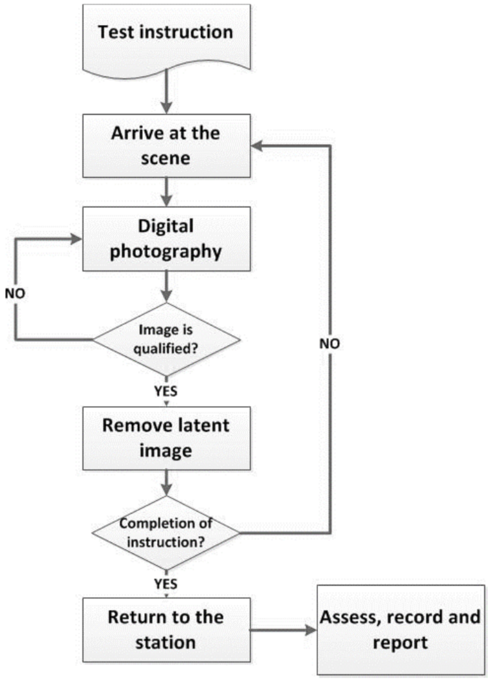

Fig. 2. Automatic welding process of X-ray image

ate correlations (more than one variable). In our solution, we use multiple linear regression models to study multivariate correlation. In wireless sensor networks, multi-variable correlation method is used to reduce the data transmission and the prediction accuracy of the proposed method.

Suppose a sensor node has p sensing units, and the collected properties are x_j, $j = 1, 2 \ldots, p$. The overall independent variable compression scheme is operated as follows:

$$y_i = 1 + \beta_1 x_{i,1} + \beta_2 x_{i,2} + \cdots + \beta_p x_{i,p-1} \,. \tag{1}$$

Here, y_i represents the response value attribute, while the $x_{i,1}, x_{i,2}, \ldots, x_{i,p-1}$ are the remaining $p-1$ properties at a given time i. We can express all the actual measured values as an m-dimension vector

$$Y = \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_m \end{pmatrix} . \tag{2}$$

We can express all the predictive factors in the form matrix $m \times (p-1)+1$

$$X = \begin{pmatrix} 1 & x_{11} & x_{12} & \cdots & x_{1(1-p)} \\ 1 & x_{21} & x_{22} & \cdots & x_{2(1-p)} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & x_{m1} & x_{m2} & \cdots & x_{m(1-p)} \end{pmatrix} . \tag{3}$$

Now the regression coefficient may be written as a p-dimensional vector:

$$\beta = \begin{pmatrix} 1 \\ \beta_1 \\ \vdots \\ \beta_{p-1} \, . \end{pmatrix} \tag{4}$$

Using a linear algebra symbol (1) may be represented as $Y = X\beta$. In order to estimate β, we can use the least square method:

$$\sum_{i=1}^{m} \left[y_i - (1 + \beta_1 x_{i,1} + \beta_2 x_{i,2} + \cdots + \beta_p x_{i,p-1})\right]^2 = \min\,, \tag{5}$$

so that

$$\beta = \left(X^{\mathrm{T}} X\right)^{-1} XY\,. \tag{6}$$

3.2. Parameter setting of distributed regression algorithm

In wireless sensor networks, the substitution method of transmitting all measured values is to establish a regression model of the network data and only transfer the model coefficients. This processing method can reduce the transmission of packets and reduce the redundancy, which helps to extend the network life cycle. For example, replace the original measured value that extracted from the node every 10 seconds. Suppose that we have ten original readings for each attribute in the sampling time, as shown in the following Table 1.

4. Result analysis and discussion

In order to analyze the validity of the regression method and verify the correctness of the proposed model and algorithm, we design the experiment in this section to verify the performance of the proposed method. In a small wireless sensor network, implement regression strategy. In the experiment, the initial energy of each node is only 0.5 J and the 200 byte control packet at the beginning. Cluster head node at the beginning of each round is determined to continue for more than and 20 seconds. When the sensor is transmitting or receiving the data in the network, or performing the regression operation, the node will produce the energy consumption. The following Fig. 3 shows that in the protocol and LEACH protocol, how the total amount of energy consumption per round of network changes with the time of the simulation.

Table 1. Ten raw data for the properties

frequency	wind power	flow	voltage	instrument temperature	pipe temperature	sink temperature	sink level	time
50.00	6.29	11.32	378.00	11.16	21.20	28.91	1.21	1
50.00	6.29	11.40	377.00	11.18	21.22	28.92	1.21	2
49.78	5.98	11.05	377.00	11.18	21.21	28.91	1.21	3
49.15	5.79	10.88	378.00	11.18	21.22	28.91	1.21	4
50.00	6.14	11.10	379.00	11.18	21.22	28.91	1.21	5
49.52	5.95	11.02	381.00	11.21	21.21	28.91	1.21	6
49.71	6.11	11.29	383.00	11.22	21.20	28.92	1.21	7
50.00	6.09	11.20	378.00	11.23	21.23	28.92	1.21	8
50.00	6.07	11.05	372.00	11.22	21.22	28.90	1.21	9
49.04	5.60	10.55	365.00	11.22	21.21	28.91	1.21	10

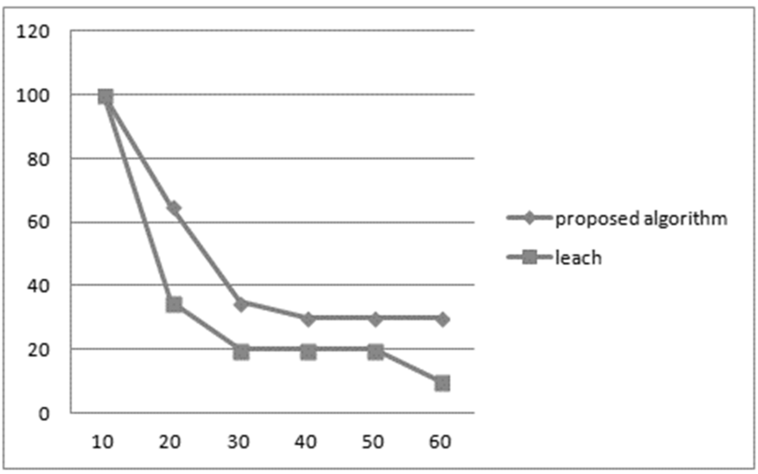

Fig. 3. Total energy consumption per round

From the analysis of the experimental results, we can see that, for each attribute, the absolute value of the error is very small. For power sampling, sampling time error at the end of the absolute value is the maximum and is as high as 9.5 %, which is lower than some preset error thresholds.

5. Conclusion

In the process of the construction of oil engineering, especially of the long oil pipeline, welding and nondestructive testing of pipeline and pipeline are the keys of the construction process. The quality of welding is an important guarantee for the construction quality of the project. X-ray detection is an important means to detect the quality of welding. For along, the welding spot detection mainly uses the X-ray film photography method, but the film photographic method has the problems of high cost, long cycle, low efficiency, serious pollution and so on. X-ray imaging provides a good technical support for solving this problem. In non-destructive testing of long oil pipeline, the method of weld quality inspection and analysis based on X-ray imaging technology can enhance the core technology competitiveness, improve the efficiency of welding seam detection, and reduce the production cost. This provides strong technical support for the construction of oil field infrastructure and the construction of large scale oil and gas transmission pipeline network. With the analysis of the weld quality detection characteristics of long distance oil pipeline and the comparison of several common methods of X-ray image, this paper solved the problem of weld quality evaluation. Based on the comprehensive application of X-ray weld quality detection and analysis technology, this paper presents an intelligent evaluation method of weld quality based on X-ray digital imaging. The hybrid intelligent mechanism is applied to the identification and evaluation of the weld quality, which realizes the intelligent method for the identification and evaluation of the quality of the weld seam. In this paper, we put forward the evaluation index of welding quality based on X-ray image, and use the wireless transmission network based on the multi-variable linear regression model to optimize the welding quality evaluation. Through simulation experiments, the accuracy and feasibility of this method are determined, which provides a theoretical support for the intelligent analysis method of automatic welding quality based on X-ray imaging.

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