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A Real-time Monitoring Method of Prestressed Tubular Piles Construction Based on Machine Vision

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Abstract: Prestressed tubular piles are a kind of workpiece commonly used in infrastructure construction of oil and other industries. The prestressed tubular piles shall be vertical to the ground at all times during installation. In engineering practice, professionals are usually required to monitor at all times. This method is easy to lead to personnel fatigue and error. Aiming to this, in this paper, a real-time monitoring method of prestressed tubular piles construction state based on machine vision is proposed and verified with the field data. The proposed method can realize the real-time vertical monitoring of prestressed tubular piles during installation. The research results can provide a reference for the assistance and automatic monitoring of the prestressed tubular piles installation process.

Keywords: Machine Vision; Prestressed Tubular Piles; Construction Status; Real-time Monitoring; Automatic Auxiliary System

1. INTRODUCTION

Prestressed tubular piles are prefabricated in prefabricated component processing plants, maintained, and after reaching design strength, transported to the construction site and driven into the soil with a pile driver. Prestressed tubular piles are very commonly used in the infrastructure of petrochemical, oil and gas fields, and other industries. In the installation process, the verticality of the prestressed tubular pile is one of the key control points for the engineering supervisors to supervise on the sidelines. In engineering practice, the verticality of the prestressed tubular pile is monitored by the method of manual measurement with double latitude and longitude instruments. This method requires technicians to keep their attention for a long time, which easily leads to personnel fatigue and thus measurement error, which in turn affects supervision accuracy. Machine vision technology is not limited by human physiology and can theoretically work well for an unlimited period of time. It is an excellent complimentary technical means of manual monitoring.

Visual measurement is a non-contact, high-precision, low-operation measurement technology, which has been widely used in various industries. In terms of small-size objects, Yoon et al. studied the size measurement of the micro workpiece, from camera image acquisition to image processing, and then measure its size [1]. The results suggest that measurement accuracy is very high, reaching 0.5um. Aiming at the measurement of the inner diameter of the workpiece in a complex environment, Kawasue et al. used robot technology is used to collect the visual data, and then the image data is processed to obtain the inner diameter parameters of the pipe [2]. The results reveal that the average measurement error can be controlled within 0.5mm. Lahajnar et al. studied the size measurement of the electric disc [3]. In this work, the image information of both sides of the electric disc was obtained by using a high-precision CCD sensor and processed by using a designed algorithm. The results suggest that the measurement result can be obtained within 0.3s, and the accuracy of the system can reach 0.3mm. In terms of long-distance large-scale object measurement, Liang Pu and others successfully used vision technology to realize real-time monitoring of aircraft body dynamic deformation in large aircraft wind tests [4]. Li et al. used machine vision technology to realize real-time measurement and monitoring of airborne antenna [5]. Furthermore, Wei et al. successfully realized the real-time monitoring of the vibration of the rotor system of a heavy helicopter in the working process by using machine vision technology [6]. The feasibility of real-time and accurate monitoring of micro deformation/movement in the working process of large machinery using machine vision technology is verified. Silvatti [7] and Sarafraz et al. [8] further expanded the application field to underwater. In these studies, machine vision technology has been used to accurately measure objects with different features and sizes in a variety of scenes, which verifies the applicability and robustness of machine vision technology in the field of object size measurement.

In the field of machine vision, OpenCV is an open-source machine learning library based on an Apache 2.0 license. It provides interfaces such as Python, Ruby, Matlab, and other languages. With OpenCV, many general algorithms in image processing and computer vision can be achieved. OpenCV can run on Linux, Windows, Android, and Mac OS operating systems, which makes it suitable for the actual application of engineering. At present, OpenCV has been widely used in object recognition, image segmentation, face recognition, action recognition, motion tracking, motion analysis, structural measurement, and other fields.

Based on this, a real-time monitoring method for the construction status of prestressed pipe piles based on Machine Vision Technology (specifically OpenCV) is proposed in this paper, so as to realize the side station automatic monitoring during the construction process and to provide assistance and support for manual supervision. The following parts of this paper are Section 2, Method; Section 3, Discussion & Conclusion.

2. METHOD

2.1 Overview

The most important control index of prestressed tubular piles during installation is verticality. The prestressed tubular piles shall be vertical to the ground surface at all times during installation. Therefore, in engineering practice, it is usually necessary to arrange one or more professionals to use theodolites and other professional instruments to measure and control the verticality in the whole installation process. In this process, due to the long duration of the operation, the possibility of error caused by the fatigue of personnel and increased the possibility of errors. This problem can be solved to a great extent by using automatic machine. As mentioned above, the object size measurement method based on machine vision technology has shown high accuracy and robustness in the measurement of small and large workpieces. By measuring the size of the prestressed tubular piles in the vertical direction and comparing it with the specified size, using the triangular edge length relationship theorem, you can determine the verticality of the prestressed tubular piles. The specific modeling steps are described in detail in 2.2.

2.2 Model Construction

In this paper, OpenCV technology is used to construct the measurement method of prestressed tubular piles in the vertical direction. The specific steps are as follows.

Step1: Construct a measurement unit pixel number indicator. Define a ratio, (Pixels Per Metric, PPM) to measure the number of pixels per given unit of measure. Utilizing PPM, we can obtain the size of any object based on an object of known size as a reference. We used the benchmark as a reference, and ensured that its position is relatively static within the field of view of the sensor. This enables us to recognize the contour size of their positions and facilitate further information extraction. By ensuring that the posts are relatively stationary in the sensor's field of view, we can arrange the contour areas of the objects in the field of view from left to right. Employing the benchmark, which always corresponds to the first contour region in the sorted list, the PPM to measure the prestressed tubular piles in the vertical direction can be fined as:

$$PPM = PS / RS \tag{1}$$

where PS is the pixel size in the vertical direction and RS is the real size in the vertical direction.

For instance, the real size of the benchmark is 5 meters. Now, we assume that the benchmark pixel in the image is 1500 pixels. Then one can obtain PPM:

$$PPM = 1500\,px / 500cm = 3\,px / cm \tag{2}$$

Therefore, in the image, there are 3 pixels per centimeter. With this ratio, we calculate the size of other objects in the image.

Step2: Construct a measurement function based on imutils and midpoint. Based on the constructed PPM, the measurement of object size in images based on imutils and midpoint can be realized. The midpoint function is used to calculate the midpoint between two (x, y) coordinates. Here, we use two parameters, – image, which is the path of our input image, including the object we want to measure, – width, that is, the height of our reference (cm), and the leftmost object identified in the image path image.

Step3: Image loading and preprocessing. Load our image from the sensor, convert it to grayscale, and then smooth it using a Gaussian filter. Then we perform edge detection and expansion & smoothing to eliminate any gaps between edges in the edge graph.

Step4: Contour detection. Find the contour lines, that is, the contour lines corresponding to the objects in our edge map, and then arrange these contour lines from left to right (so that we can extract the reference objects) in line 19.

Step5: PPM value initialization and noise filtering. Initializes the PPM value based on the measured size of benchmark, and, then, checks and verifies the value of each contour region. Cycle through each individual profile value. If the contour area is not large enough, we will discard the area and consider it as the noise left by the edge detection process. If the contour area is large enough, we will calculate the rotation bounding box of the image.

Step6: Object image boundary detection and correction. The rotated bounding box coordinates are arranged in order in the upper left corner, upper right corner, lower right corner, lower left corner.

Step7: Border (medium) point calculation. Disassemble the values of the orderly boundary frames in front of us, calculate the middle point between the upper left corner and the upper right corner, and then calculate the middle point between the lower left corner and the lower right corner.

Step8: Measurement results calculation. First of all, we calculate the distance between Ouji Miles between the intermediate sets. DA variables will include height distance (in pixels), and DB will maintain our width distance. Now that we have defined the PPM variable, we can measure the size of each object in the image. The method of calculating the size of the object is to divide the distance from the Ouji mile through the PPM measurement value。

Step9: Vertical monitoring results judgment and output. Compare the measured vertical height of prestressed pipe pile with its nominal height. If the error is less than 0.5%, it is considered that the prestressed pipe pile is still vertical to the ground at the current time; Otherwise, it is considered that the construction state of prestressed pipe pile is abnormal, and the system sends out sound and light alarm signals.

The workflow of the real-time monitoring method for the construction state of prestressed tubular piles constructed in this paper is as shown in Figure 1.

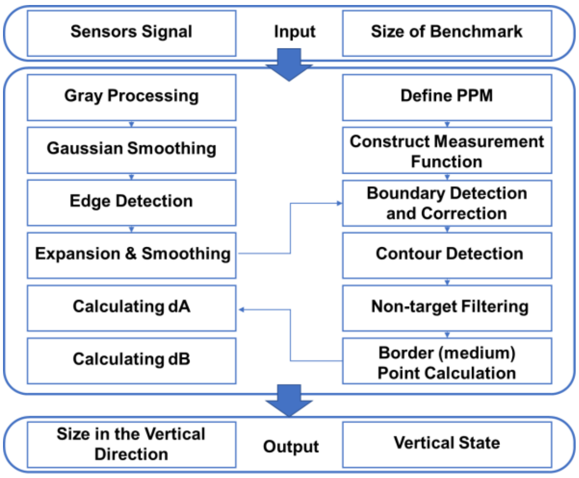


Figure. 1 Workflow of the real-time monitoring method for the construction state of prestressed tubular piles.

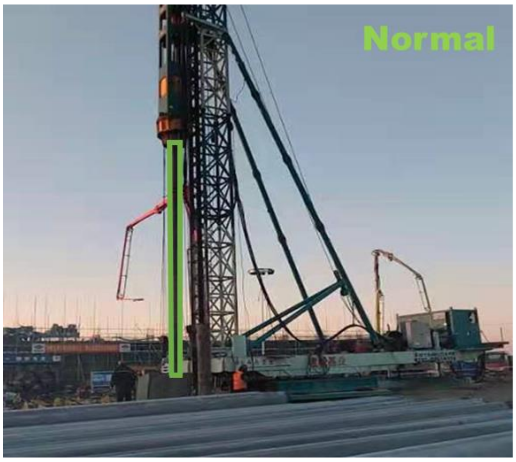
2.3 Verification & Application

Verification: the prestressed tubular piles with a vertical height of 10m is selected as the target to verify the effectiveness of the monitoring method. The specific steps are as follows: firstly, use the theodolite to measure the vertical height a of the prestressed tubular piles leaking out of the ground at three time points; Then, the vertical height B at these three time points is measured by the established method; Finally, compare the difference between a and B. The validation results are shown in Table 1.

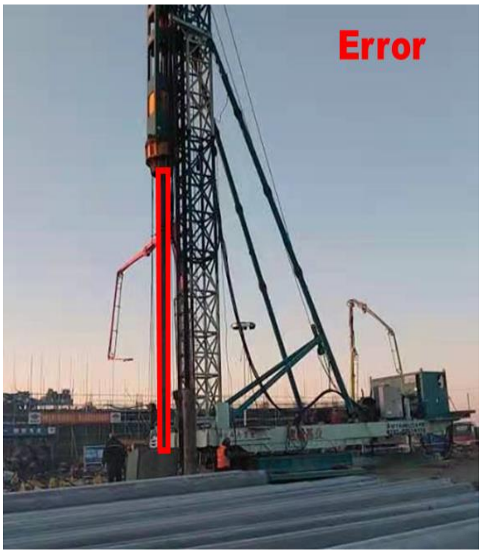
Table 1. Validation data

Items	Vertical height at t_1	Vertical height at t_2	Vertical height at t_3
Actual value A	1000 cm	7500 cm	5000 cm
Measured value B	1001.33 cm	7498.66 cm	4998.33 cm
Error	0.13%	0.178%	0.154%

Application: select a prestressed tubular piles installation process, while professionals use theodolite to monitor, use the method established in this paper to monitor at the same time. During installation, the verticality of prestressed pipe pile at time point T3 deviated from the specified value. The technician gave an alarm. Thanks to the real-time calculation of the system, the system built in this paper found the deviation earlier and successfully sent out the alarm signal. The alarm interface is shown in Figure 2.



(a) The frame before the alarm



(b) The frame after the alarm

Figure. 2 Alarm interface

3. DISCUSSION AND CONCLUSION

The installation of prestressed tubular piles requires manual monitoring. Traditional methods can easily lead to personnel fatigue and error. Based on this, this article builds an automatic monitoring method based on machine vision technology. Verifying and application results reveal that the method presents a high measurement accuracy, and the alarm signal is issued correctly through the comparison of the specified value. At the same time, thanks to the real-time nature of the work platform used, the construction method issued an alarm earlier than the manual monitoring method. The results suggest that the real-time monitoring method of the construction status of the prestressed tubular piles installation in this paper is effective and can provide reference for relevant research and engineering practical applications.

4. REFERENCES

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