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Sewage Particle Concentration Measurement Based on Image Processing Technology

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The concentration of suspended particle in sewage offers an important reference for testing water quality. This paper sheds new light on suspended solid concentration measurement with the Image Processing Technology (IPT) based upon different light reflex characteristics of water and suspended particles. With the Matlab, the probability-based insolation non-uniform correction algorithm and the Otsu threshold segmentation algorithm are used to simulate the sewage image, extract the area feature and calculate the concentration of suspended particles in sewage, which, in relation to true values, proves that the suspended solid concentration measurement based on the IPT seems more accurate and feasible, thus laying the foundation for studying the solid-liquid separation technology.

1. Introduction

Industrial effluents, as well as rainfall runoffs from cities and farms, all contain toxic chemicals (Luo et al., 2014). If the suspended solids in water carry toxic chemicals, they may turn into potential sources of water pollutants as flowing with water to the downstream because these solids remain in water for a long time in a suspended way and not easily get deposited on the water floor. How to accurately test the concentration of suspended particles in sewage is the key to the quality assurance of wastewater treated by the sewage treatment process. It is also a key parameter that helps accurately determine the sludge discharge time of the sludge pump (Baker and Kasprzyk-Hordern, 2011; Jakimska et al., 2014). Suspended solids, once contaminated, not only threatens the water environment but also triggers risks to human health (Abda et al., 2009; Grant et al., 2013). It is estimated by the US Environmental Protection Agency (EPA) that 10% of lakes, rivers, and bays in the United States suffer from the contamination from suspended matters carrying toxic chemicals which are deposited and passed on to the food chain by ways of fish and benthic organisms (Loisel et al., 2014). How to effectively test the concentration of suspended solids in water is fundamental to assessing water quality and potential adverse effects of suspended solids on potable water. To test the total content of suspended solid transported by a river at a certain time can help determine the environmental implication of the reservoir and estimate its life span. As one of the key parameters, the concentration of suspended solids is also required in water and effluent treatment processes to measure the working conditions at each stage. The traditional sewage suspended particle concentration testers are not linear and instant. For those contact measurement devices, longstanding immersion and scouring in sewage not only spoils their accuracy but also shortens their service life (Sugimoto and Kawaguchi 2009). To make up for these gaps, this paper proposes a new IPT-based test method for measuring suspended solids in sewage.

2. Test algorithm

Computer technology and IPT underlie this new IPT-based measurement method for the concentration of suspended solids in sewage (Jouon et al., 2008). This method requires a camera to be hermetically installed in a special underwater tank in which a glass sash should be equipped for the camera to record the real-time status of water flow containing the suspended solids. The computer-controlled measurement analysis system analyzes the suspension concentration and size distribution. It depends its measurement accuracy on the resolution of the video system and the IPT. The process of algorithms involved in the sewage suspended

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particle concentration measurement based on the IPT is shown in Fig. 1. Images acquired by the CMOS are processed by the image processing algorithm to extract the eigenvalues and calculate the concentration of suspended particles in sewage.

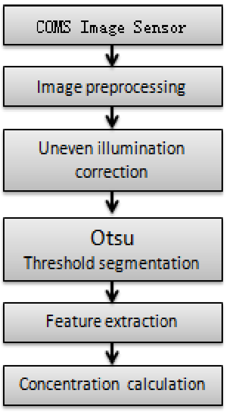

Figure1: Detection algorithm flow chart

The sewage treatment environment is complex, and the acquired images are characterized by high noise and large interference. It is therefore required to pretreat the acquired images, as shown in Fig. 2.

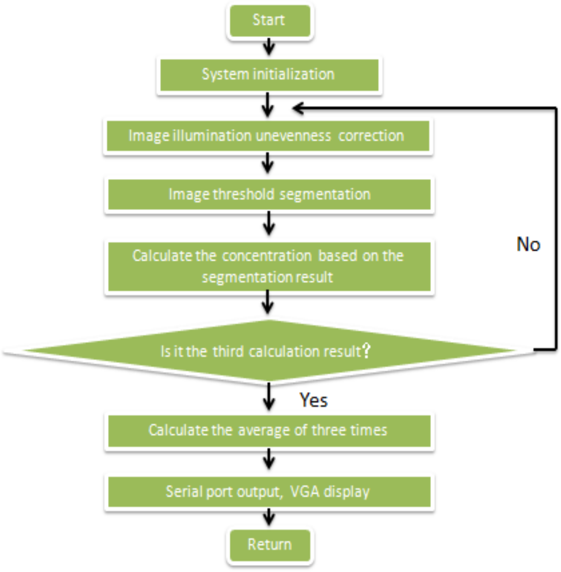

Figure 2: System flow

Insolation non-uniform correction algorithm can remove the uneven illumination phenomenon. Then, the fuzzy threshold segmentation algorithm binaries the images and calculates the concentration of swage suspended particles. In order to improve the test accuracy, the calculation results from three consecutive processes are averaged to obtain the final concentration of suspended solids in sewage, then displayed in real time by the VGA, and sent to the upper computer via the ZigBee module.

2.1 Insolation non-uniform correction

When acquiring sewage images, illumination inhomogeneity may occur due to the odds of the light sources, so that the image threshold segmentation will be greatly spoiled. The concentration of suspended particles in sewage is also inaccurate. It is required to perform insolation non-uniform correction. In this paper, a probability-based insolation non-uniform correction algorithm is used by the following processing procedures:
(1) Select an area with a certain size from the original image, calculate the mean value of pixels, u, and the variance σ in the area, use max (min, μ-3σ) as the background gray of the area, combined with the minimum

gray scale of the pixels in the area; (2) Expand the background gray scale of the area to the size as the original image is, that is, the estimated background illumination image; (3) Subtract the estimated background illumination image from the original image to eliminate uneven illumination; (4) Median filter; (5) Adjust the gray scale of the filtered image to eliminate the phenomenon of too darkness and too brightness formed during the subtraction of images.

2.2 Otsu threshold segmentation

Due to different reflection characteristics of water and suspended particles relative to the light, in sewage imaging process, image pixels will generate in different hues of brightness and darkness. The Otsu threshold segmentation algorithm is used to separate the pixels that characterize water and suspended solids in sewage images from each other, realizing the binarization of sewage images (Pfannkuche and Schmidt 2003). The Otsu is an efficient algorithm proposed by Japanese scholar Otsu in 1979. It captures such an idea that the threshold is first set, the images are classified into two parts, the target and the background types, calculate the probabilities of pixels, the mean value of gray scales and the gray scale variance between the two domains, respectively, where the variance is a function relative to the threshold. When the variance between the two domains takes the maximum value, the corresponding threshold is optimal. For example, an image with a gray scale in [0,L-1], $n_i$is the number of pixels in gray value; N is the total number of pixels; p_i is the probability of occurrence of a pixel with a gray value i. The formula is shown in (1):

$$p_i = n_i / N, i = 0,1,2,L,L-1 \tag{1}$$

$$N = \sum_{i=1}^{L-1} n_i \tag{2}$$

The threshold K(0≤K≤L-1) is used to divide the image pixels into two types, the background images C_0=(1,2,L,K) and the target images C_1= {K+1,K+2,L,L-1} according to the gray levels, the statistical mean value of the image gray scales is shown in formula (3):

$$u = \sum_{i=1}^{L-1} i p_i \tag{3}$$

The probability of C_0 is

$$w_0 = \sum_{i=1}^{K} p_i = w(K) \tag{4}$$

The mean value of C_0 is

$$u_0 = \sum_{i=1}^{K} i p_i / w_0 = u(K) / w(K) \tag{5}$$

The probability of C_1 is

$$w_1 = \sum_{i=1}^{L-1} p_i = 1 - w_0 \tag{6}$$

The mean value of C_1 is

$$u_1 = \sum_{i=1}^{L-1} i p_i / w_1 = \frac{u - u(K)}{1 - w(K)} \tag{7}$$

As above, $u=w_0u_0+w_1u_1$, the variance between classes is defined as

$$\sigma^2(K) = w_0(u - u_0)^2 + w_1(u - u_1)^2 = w_0 w_1 (u_0 - u_1)^2 \tag{8}$$

When K falls within [0,L-1], according to the formula (8), the threshold K when $б^2$(K) takes the maximum value is the optimal threshold from the Otsu algorithm.

3. Test results and analysis

In this test, we take the sewage in the oxidation ditch of the sewage treatment plant, Shouchuang Water Affairs in Huainan, as the object. At five different times, the sewage images in the oxidation ditch right after the aeration are acquired as test samples, respectively recorded as Sewage1, sewage2, sewage3, sewage4, sewage5, with different concentrations, set to a resolution of 2592*1944. Image pretreatment needs to convert the color images to grayscale ones, as shown in Fig. 3. a is the sewage1 in RGB color system, which comprehensively reflects the feature information of the sewage image. On the grounds of mapping relationship between the RGB and the grayscale images, the corresponding grayscale image after conversion is shown in Fig. b.

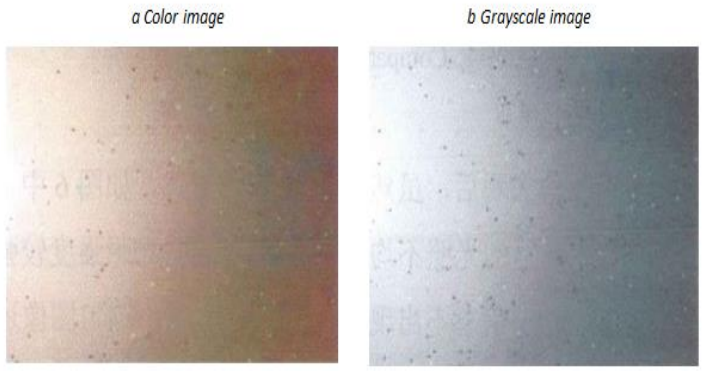

Figure 3: Color image to grayscale image

This conversion process discards the color information of the images. Color image is usually 3 bytes per pixel, and gray image takes 1 byte per pixel. After it is converted from color to grayscale, the gray value of the pixel is the pixel brightness of the color image. In order to avoid the lack of image details during image processing, the uneven illumination image to be measured must be converted into a uniform type. This paper uses the probability-based insolation non-uniform correction algorithm to correct sewage image with uneven illumination, and the specific image process algorithm is shown in Fig. 4.

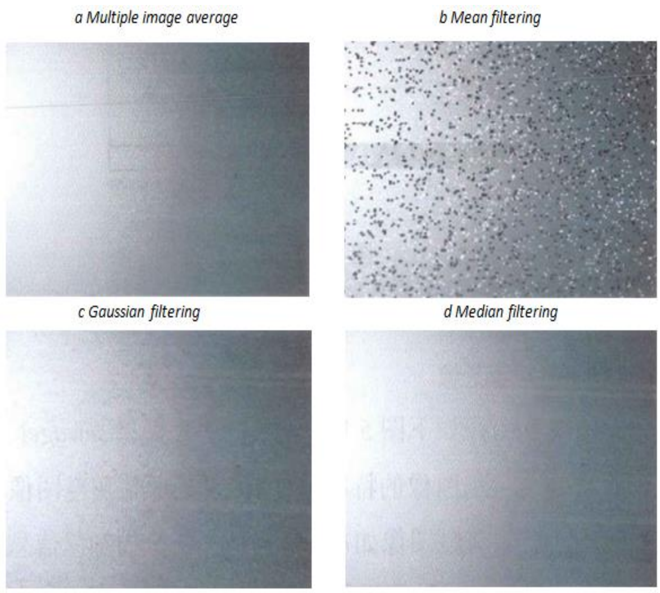

Figure 4: Comparison of filtering methods

For the sewage 1, the Matlab is used to simulate it in accordance to the algorithm flow in Fig. 1. The Otsu algorithm performs threshold segmentation on those images after the insolation non-uniform correction (Wu, Cui et al. 2013). Similarly, the Maltab function also works for the sewage2, sewage3, sewage4, sewage5, and the function Bwarea () is then used to extract the binary image eigenvalue, that is, the pixel area of the binarized image with a pixel value of 1, i.e. characterize the pixel area of water as shown in Table 1 below.

Table 1: Area comparison

Sample image	Sewage1	Sewage2	Sewage3	Sewage4	Sewage5
Adaptive Otsu algorithm	2.4892e+06	2.9931e+06	2.7663e+06	2.8066e+06	2.5648e+06

The resolution of the CMOS is 2592*1944. According to formula (9), m represents the ratio of the pixel area of the suspended particle to the pixel area of the whole sewage image, as shown in Table 2 below, wherein, n represents the pixel area in which the pixel value is 1 in the binary image calculated with the Bwarea() function.

$$m = [1 - n(2592 \times 1944)] \times 100 \quad (9)$$

Table 2: Area ratio

Sample image	Sewage1	Sewage2	Sewage3	Sewage4	Sewage5
Adaptive Otsu algorithm	50.3	40.8	45.6	44.0	48.5

In combination with the depth of the sewage in the oxidation ditch, the concentration of suspended particle in sewage will be calculated based on the ratio of the pixel area of the suspended particles to the overall pixel area of the sewage image, as shown in Table 3 below.

Table 3: Concentration value comparison

Suspended particle concentration value(mg/L)	Sewage1	Sewage2	Sewage3	Sewage4	Sewage5
Otsu measured concentration value	7930	6450	7200	6940	7650
True concentration value	7880	6480	7250	6890	7700

It is known that the error between the concentration calculated by the image method for suspended particles in sewage and the true value is less than 0.01, and falls within the allowable range, achieving the test effect as expected.

4. Conclusion

Computer technology and IPT underlie this new IPT-based measurement method for the concentration of suspended solids in sewage. This method requires a camera to be hermetically installed in a special underwater tank in which a glass sash should be equipped for the camera to record the real-time status of water flow containing the suspended solids. In this paper, the image processing technology is used to detect the concentration of suspended particles in wastewater. Combined with Matlab tools, image processing algorithm was used to carry out simulation analysis on five sets of sewage images collected, calculate the concentration of suspended particles of sewage, and compare with the real value, and obtain the accuracy and feasibility of the detection of suspended particles of sewage based on image processing. It also shows that the image processing technology is of great significance to the study of solid-liquid separation. The system has the advantages of good real-time, high detection accuracy, safety and reliability and easy installation.

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