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Automatic Detection and Assessment System of Water Turbidity based on Image Processing

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Abstract

The realization of automatic control system of releasing flocculating agent is one of the bottlenecks in the automation process of waterworks. For various reasons, most of waterworks in China decide the dosing amount just by artificial methods, which may lead to great subjectivity. It can result in direct economic losses and threaten residents' drinking water safety. To solve the problem, based on digital image processing and pattern recognition technology, the paper presents an advanced and practical automation scheme, trying to control the releasing of flocculating agent. According to the characteristics of alum images captured from waterworks, by comparing the effects of many vision algorithms, the paper selects a suitable combination and tries to implement it with EmguCV. On next step, the paper implements feature selection and classification with LibSVM. The experiments show that, the system designed in this paper is reasonable and feasible.

Keywords*: Digital Image Processing Technique; Feature Selection; EmguCV; LibSVM*

1. Introduction

With the development of computer technology, image technology and classification technique is used in many domains [1], [2]. Using image technologies to realize automatic control system of releasing flocculating agent means a small miscalculation. Thereby, it can cost us less in man-power, material and money and arrives at a good level with economic benefits and social benefits. And the water residents drink is more clean. Based on image theory, a fully functional and effective scheme is presented in the paper which affords theory and practical warranty to control the releasing of flocculating agent. The automatic system is composed of software part (figure 1) and hardware part (figure 2) : hardware part mainly includes the image collecting device and motor control system, and the software part is the application of image processing system.

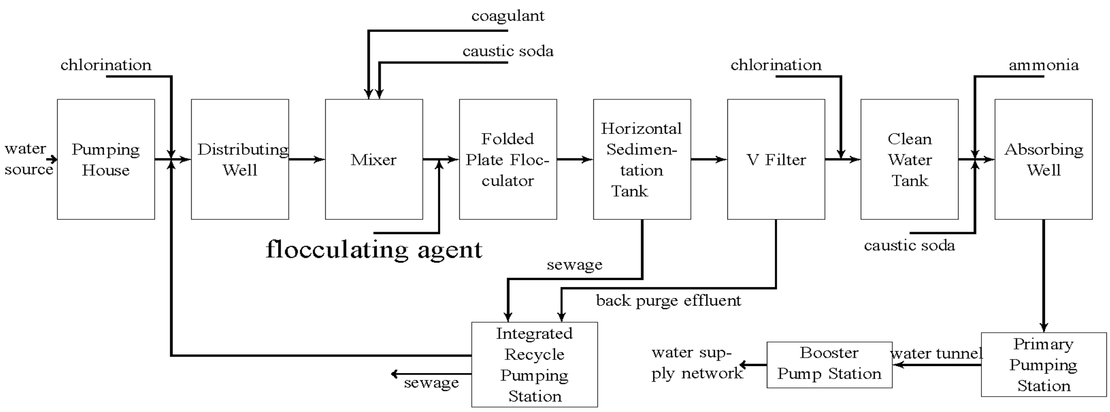

Figure 1. Manufacturing technique of waterworks

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This paper focuses on the software part. In this research we use alum as flocculating agent. According to the characteristics of alum images, by comparing the effects of algorithms, the paper selects a suitable algorithm combination and tries to implement it with EmguCV. Next work is feature selection and classification with LibSVM. By category, we can get current alum concentration. Thus we know the quantity we dose is overmuch, little or just fine. Based on the results, we can decide the right amount we should dose next time.

(a). Experiment place - a waterworks

(b). Image acquisition device

Figure 2. Experimental environment

2. Research Method and Realization

To implement the system shown by Figure 3, the paper designs the hardware shown by Figure 4 by which we introduce information technology into the waterworks management system. The hardcore of the system is the software part. Figure 3 shows the overall frame of the system.

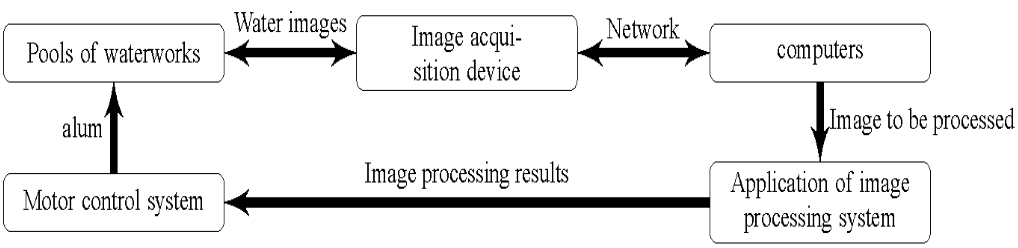


Figure 3. The overall frame of the system

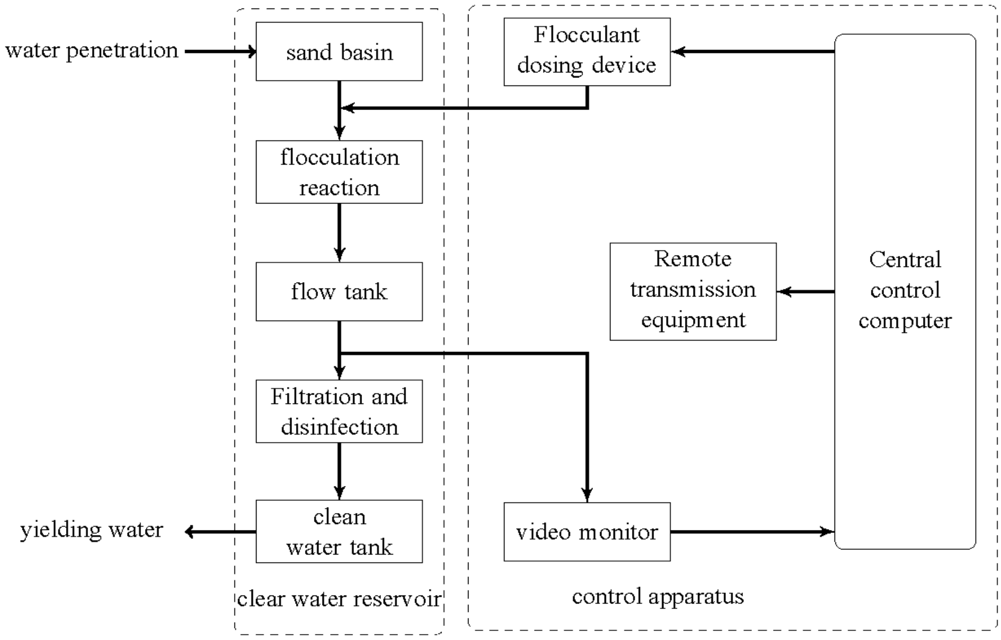


Figure 4. The overall frame of the system

The paper focuses on the algorithmic manipulation. By constantly testing, improving and comparing, we get a set of effective algorithms to process alum images which is presented in the following part of this paper. Figure 5 shows the algorithm framework.

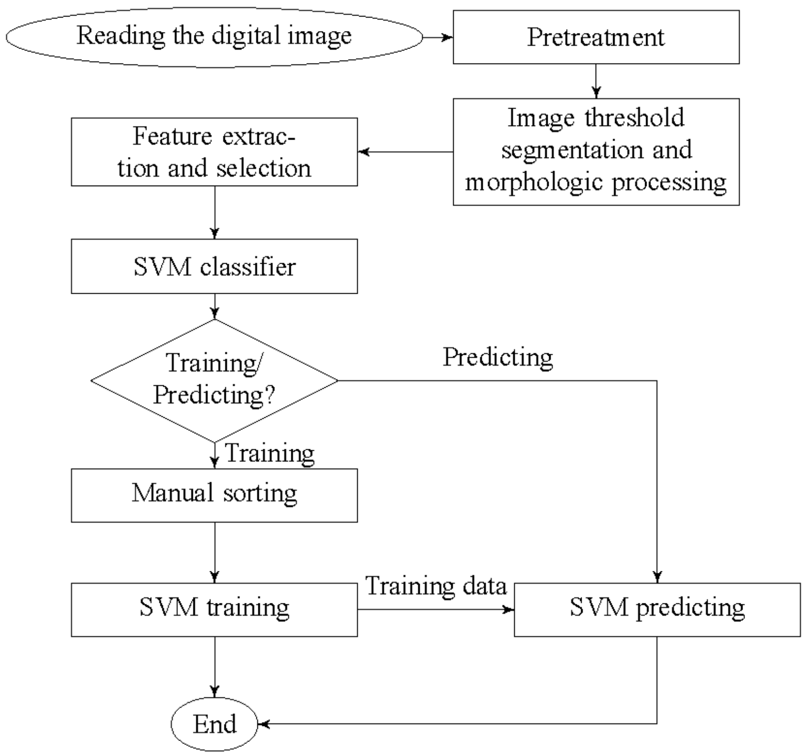


Figure 5. Algorithm framework

2.1. Pretreatment

This part can be completed in three steps shown by Figure 6. Cutting the image is supposed to improve computer processing speed and remove disturbances from watermarks in the image edge. The images acquired from the pools are 24-bit color ones and described in RGB model. As a RGB model image is not suitable for direct use in image recognition, we gray it. According to ITU-R BT.709 standard regulations, the paper takes the conversion formula shown by formula (1).

$$H = 0.212671R + 0.715160G + 0.072169B \quad (1)$$

As for image enhancement, the paper uses exponential transform as formula (2). Figure 7 shows the treatment effect of this part.

$$g(x,y) = b^{c[f(x,y)-a]} - 1 \quad (2)$$

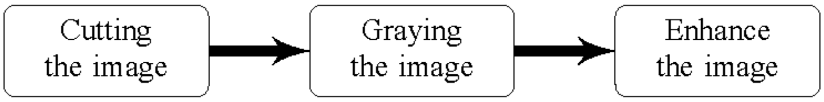
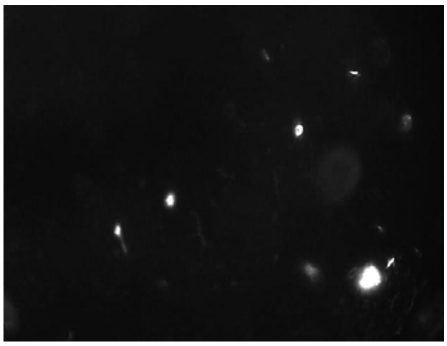


Figure 6. Pretreatment

2.2. Image Segmentation and Morphological Processing

According to the characteristics of alum images and the quality of processing results, the paper chooses 2-D maximum entropy threshold algorithm. Entropy is a characterization of the average information. The algorithm which is based on the feature of point and region gray can achieve better results to present the information of an image [3]. By applying the algorithm, we can acquire the maximal information content of the target area. Segment the image of Figure 7(b), we get Figure 8(a). Mathematical morphology can be used to solve image processing problems such as noise suppression, feature extraction, edge detection, image segmentation, shape recognition, texture analysis, etc [4].

(a) an original image



(b) Pretreatment effect

(The original images used in the paper are acquired from a waterworks in Fuzhou, Fujian, China on July 12, 2011)

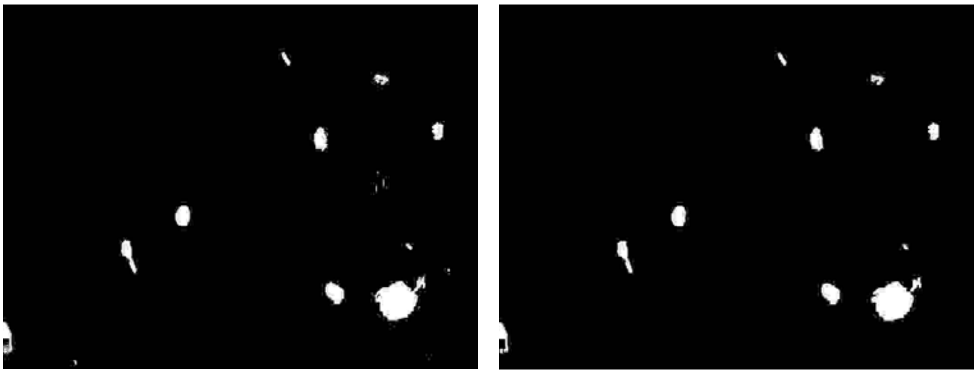
Figure 7. Effect diagram ($a = 91, b = 1.5, c = 0.1$)

The base of mathematical morphology is the theory of set. Its fundamental transformations are erosion operation and dilation operation. Erosion operation is defined as formula (3). It can be used to eliminate small objects on the image.

$$A \oplus B = \{z \mid (\hat{B})_z \cap A \neq \Phi\} \quad (3)$$

Dilation operation is defined as formula (4) which can be used to fill small cavities in the object. The operation that do erosion operation first and then the dilation operation is called opening operation. It can eliminate small objects, separate objects at slender points, smooth the boundariesy of large objects with no obvious changing of their areas.

$$A \otimes B = \{x \mid B + x \subset A\} \quad (4)$$



(a) (b)

Figure 8. (a): Segment the image of Figure 7(b) with 2-D maximum entropy threshold algorithm; (b): Morphological processing result of (a).

2.3. Feature Extraction and Selection

Generally speaking, features that can better distinguish and recognize images should have the following qualities: reliability, independence and distinguishability [5], [6]. Features the paper selects are the values of area, perimeter, format factor, the number of pixels and invariant moments. Feature area and perimeter ignore internal gray level change of objects but only care about the boundaries. Feature format factor is defined by formula (5). There are 7 invariant moments marked as $\phi_1, \phi_1, \cdots, \phi_7$. Invariant moments have invariant features of rotating, scaling and translating which is proved by Hu.M.K in 1962. In fact, for image processing, only ϕ_1 and ϕ_2 can keep the invariance well. The paper chooses ϕ_1 as one feagure. The invariant moment ϕ_1 is defined by formula (6) (η in the formula is 2nd normalized central moment).

$$e = 4\pi \frac{S}{P^2} \quad (5)$$

where: S is the value of area and P is the value of perimeter.

$$\phi_1 = \eta_{20} + \eta_{02} \quad (6)$$

Figure 9 shows all the contours of the image shown in Figure 8(b). Each parameter value of the contours is shown in table 1. So we get the concentration value of alumen ustum (*noted:* Alumen ustum is the product of reacting alum with impurities in water). However, the result is not accurate because not all contours stand for alumen ustum, for example, some can be air bubbles. Therefore, automatic recognition is necessary.

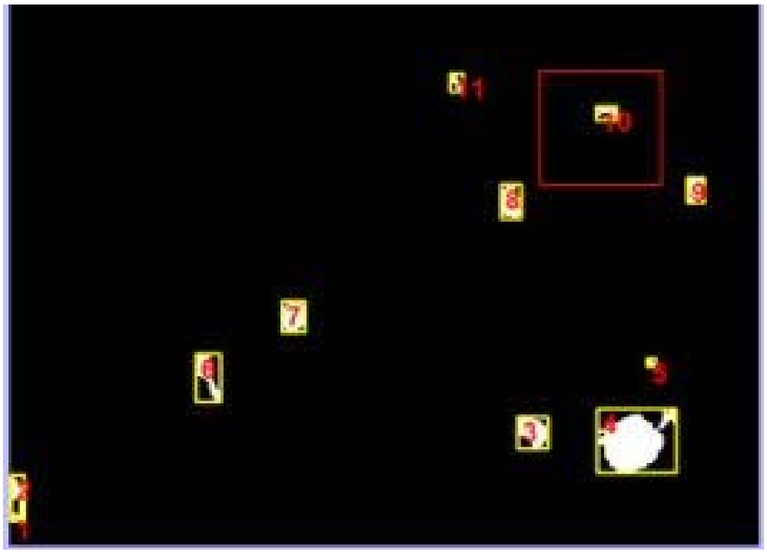


Figure 9. Figure 8b with all contours marked

Table 1. The values of characteristic parameters of the contours in Figure 9

No.	Area	Perimeter	Format factor	Pixels	Invariant moments ϕ_1
1	15	16	1.3588110403397027	4	0.188888888889
2	184.5	92.384775996208191	3.6831110230220965	22	0.517391463005
3	441	89.112697720527649	1.4336757974475594	44	0.174816558847
4	1967.5	250.75230693817139	2.5444006278302234	111	0.183145062352
5	22.5	21.071067690849304	1.5710895032991981	11	0.221646700201
6	322	104.7695517539978	2.7140925977008803	40	0.420305173256
7	374.5	76.870057225227356	1.2562409535027017	31	0.173973877163
8	341.5	80.870056986808777	1.5247377430616378	34	0.197909912424
9	222	63.798989534378052	1.4597718574653125	29	0.186444758816
10	94.5	63.556348919868469	3.403270218737628	29	0.272625717559
11	73.5	41.213202834129333	1.8399065035823541	18	0.300391829544

2.4. Automatic Recognition Of Alumen Ustum with LibSVM

The paper uses LibSVM to discriminate alum from non-alum on the premise that image processing and feature extraction is done (*noted*: LibSVM is developed by associate professor Lin Chih-Jen of Taiwan University. For SVM implementation, it is simple, wieldy, Fast and efficient). The main idea of SVM is to build a hyperplane as the decision-making surface which maximizes the separation distance between positive samples and the counter ones. It's under the principle of structural risk minimization and has best overall solver [7]. Use 'grid.py' in the 'python' subdirectory inside the LibSVM archive, we can get the best parameters c and g . c stands for penalty coefficient, g stands for gamma coefficient. Figure 10 shows the result. So we know, if $c = 512$, $g = 0.125$, we can get the best classify effect with accuracy of 75.7576% . The real accuracy is biased from this for digit limits of calculations. And if we have larger sample numbers, we can get higher accuracy.

3. Results and Analysis

After training and predicting, we can get relatively accurate concentration values of alumen ustum. If images captured in real time, we can get a curve of concentration values just like Figure 11. In Figure 11, there are two demarcation lines, 0.75% and 0.15%. Through interaction with the water plant workers, we believe that if the concentration is higher than 0.75%, the quantity of alum we put is overmuch and if less than 0.15%, it's too little. Experimental alum pictures of Figure 11 are respectively obtained in the pools whose alum amount we put is overmuch, just fine and little. The result of the experiment meets our expected goal. The trials show that the scheme presented in the paper is feasible.

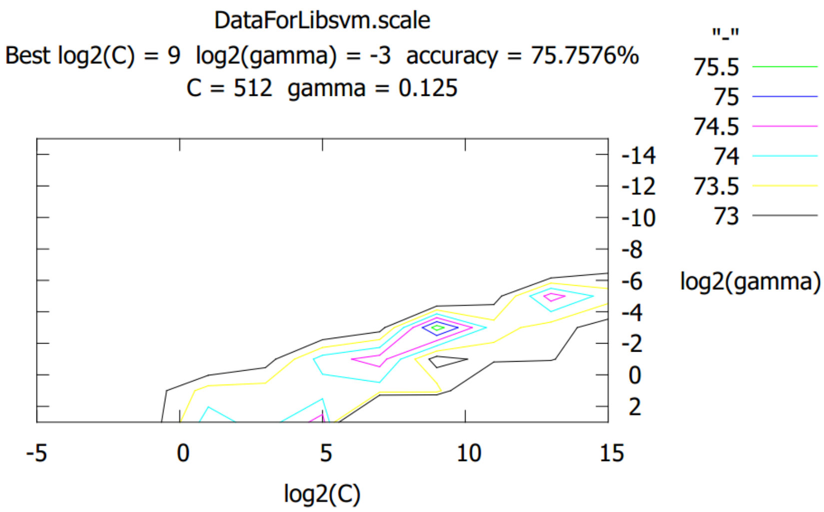


Figure 10. Parameter optimization results

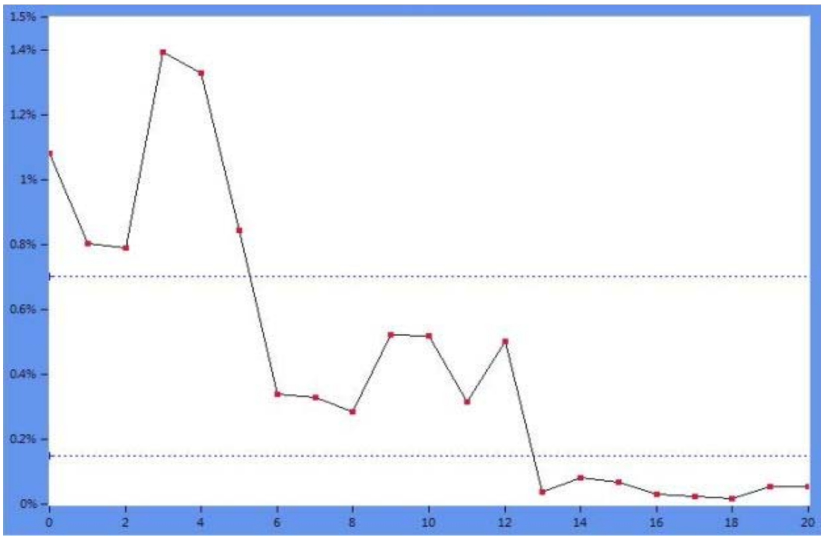


Figure 11. Real-time monitoring of concentration values of alumen ustum.
The abscissa is the time and the ordinate is the concentration value.

4. Comparison of Schemes

Many scholars are making an effort to achieve automatic recognition and analysis of alum images. The article [8] presents a recognition algorithm used to extract the texture features of alum image and constructs a multiple classifier combination structure. However this method relies more on the quality of the original image. If the original image is of poor quality, it will be difficult to achieve good results. The article [9] has no classification and identification working. So it can't reduce the interfere of impurities like air bladders. The scheme presented in this paper overcomes the above-mentioned disadvantages, which is relatively complete and reliable.

In the respective part of the image processing, there is a variety of algorithms at choice. Such as the pretreatment part, article [10] adopts linearity gray transform. And if it is applied in this paper, you can see the resulting effect is relatively poor compared with the exponential transform. In the image segmentation part, article [5] adopts the method of OSTU which also gets a good result. However, in order to provide a sufficient amount of information for post-processing, the author chooses 2-D maximum entropy threshold algorithm. In every part of the implementation, the author has selected a better algorithm and end up with an effective combinatorial algorithm for automatic recognition and analysis of alum images.

5. Conclusion

The purpose of this study is to afford theory and practical warranty to control the releasing of flocculating agent. Image processing is broken into a sequence of four steps: pretreatment, segmentation, morphological processing and feature extraction. According to the real-time and accuracy requirements of the system, the author constructs a classifier with LibSVM to reduce the interfere of impurities. The experiment responds well and the system designed in this paper is reasonable and feasible.

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