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Research Article

Implementation of Water Quality Management by Fish School Detection Based on Computer Vision Technology

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Abstract: To solve the detection of abnormal water quality, this study proposed a biological water abnormity detection method based on computer vision technology combined with Support Vector Machine (SVM). First, computer vision is used to acquire the parameters of fish school motion feature which can reflect the water quality and then these parameters were preprocessed. Next, the sample set is established and the water quality abnormity monitoring model based on computer vision technology combined with SVM is acquired. At last, the model is used to analyze and evaluate the motion characteristic parameters of fish school under unknown water, in order to indirectly monitor the situation of water quality. In view of great influence of kernel function and parameter optimization to the model, this study compared different kinds of kernel function and then made optimization selection using Particle Swarm Optimization (PSO), Genetic Algorithm (GA) and grid search. The results obtained demonstrate that, that method is effective for monitoring water quality abnormity.

Keywords: Computer vision technology, fish school motion, support vector machine

INTRODUCTION

With the rapid development of economy and technology, environmental pollution becomes more and more serous, especially water quality pollution. To prevent and cope with water quality pollution, current water quality monitoring technologies include technology of physical and chemical analysis, automatic measurement technology and biomonitor technology (Simeonov *et al*., 2010; Jang *et al*., 2011). The former two costs too much in long term and they both can not realize the comprehensive evaluation on the pollution degree of water quality. As a result, biomonitor technology featured by comprehensiveness, enrichment and continuity is gradually used. Recently, it plays a more and more important function in environmental evaluation and is considered to be prospective. Fish is the important biological indicator in biological water quality monitoring, whose motion feature and biological feature can reflect the change of water environment in a direct way and represent the current situation of environmental pollution. Many scholars at home and abroad such as Kim *et al*. (2007), Kittiwann and Nakagawa (2008), Maa *et al*. (2010), Chen *et al*. (2011), Hu *et al*. (2012) and Chen *et al*. (2009) acquired motion characteristic parameter of fish by computer vision technology (Ma *et al*., 2010), but only few proposed to monitor water quality abnormity based on those characteristic parameters. Serra-Toro *et al*. (2010), Lai and Chiu (2011) and Jin *et al*. (2011) respectively used recursive algorithm, fuzzy illation and negative selection principle to analyze the relationship between motion characteristic parameter and water quality, in order to achieve the purpose of monitoring water quality abnormity.

This study puts forward a water quality abnormity monitoring method based on computer vision technology and SVM. At first, computer vision is used to collect the motion characteristic parameters of fish school under water and then these parameters are analyzed by SVM. Finally, a language mapping model for motion characteristic parameters of fish group and water environment is established for monitoring water quality abnormity.

MATERIAL AND METHODS

Principle of sorting algorithm of SVM: The principle of SVM is a SRM standard based on statistical learning theory. When performing linear classification, the classification plane is selected at a place away from two kinds of samples; when performing non-linear classification, the non-linear classification problem is converted into a linear classification problem in higher space. Suppose the training sample set as:

$$\{(x_1, y_1), \cdots (x_n, y_n), x_i \in R^m, y_i \in \{-1,1\}\}$$

where,

x = Feature vector
y = Category sing
n = Sample size
m = Input dimension

Suppose the hyperplane equation used for classification as:

$$\omega \cdot x + b = 0$$
$$y_i[(\omega \cdot x_i) + b] - 1 \geq 0, i = 1, \cdots, n$$

At this moment, the interval of classification is $2/\|\omega\|$. The optimal solution for hyperplane should maximize $2/\|\omega\|$, i.e., minimize $\|\omega\|^2/2$. In this way, it can be converted into the following quadratic programming problem:

$$\begin{cases} \min\limits_{\omega, b} \dfrac{1}{2}\|\omega\|^2 \\ s.t. \quad y_i(\omega \cdot x_i + b) \geq 1, i = 1, \cdots, n \end{cases}$$

Eq. (3) can be converted into optimization solution of lagrangian multiplier:

$$\begin{cases} \max \; W(\alpha) = \sum\limits_{i=1}^{n} \alpha_i - \dfrac{1}{2} \sum\limits_{i,j=1}^{n} \alpha_i y_i \alpha_j y_j (x_i - y_i) \\ s.t. \sum\limits_{i=1}^{n} \alpha_i y_i = 0, \alpha_i \in [0, C], i = 1, \cdots, n \end{cases}$$

where, C is penalty factor and α_i is lagrangian multiplier. When the lagrangian multiplier is figured out, decision hyperplane can be presented as follows:

$$f(x) = \text{sgn}\left\{\sum_{i=1}^{n} \alpha_i y_i (x_i \cdot x) + b\right\}$$

b in Eq. (5) can be obtained by taking the mid-value of any pair of support vectors in two kinds.

To solve non-linear problem or inseparable problem, kernel function is introduced. In a similar way, after the lagrangian multiplier is figured out, decision hyperplane is expressed as follows:

$$f(x) = \text{sgn}\left\{\sum_{i=1}^{n} \alpha_i y_i K(x_i \cdot x) + b\right\}$$

The common kernel functions include linear kernel function, polynomial kernel function, radial basis function and Sigmoid function.

RESULTS

Water quality abnormity monitoring method based on computer vision and SVM:

Principle of water quality abnormity monitoring: SVM, a excellent pattern classifier, cam solve practical problems such as small sample, non linear, high dimension, local minimum point. In the perspective of pattern identification, fish under normal water and

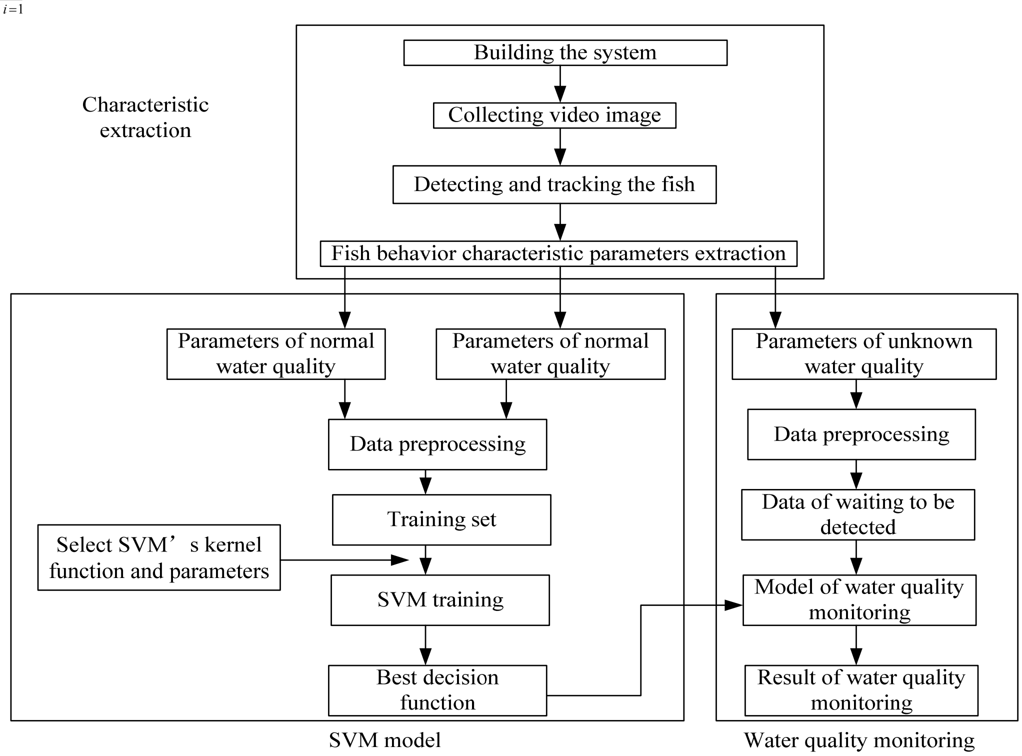

Fig. 1: Scheme of water quality abnormity monitoring based on computer vision and SVM

Fig. 2: Detection of moving fish

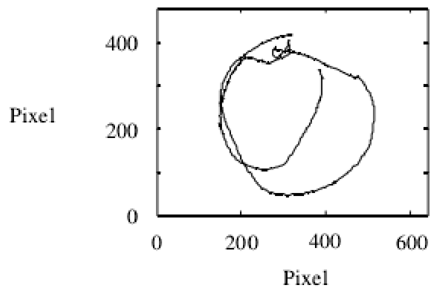

Fig. 3: Motion trails of single fish

abnormal water significantly differing in motion characteristics can be considered as two different kinds of motion patterns. Therefore, water quality abnormity monitoring belongs to classification problem. To avoid the problem of overlap of motion characteristic parameter of fish, SVM converts fish motion characteristic parameters into apparent problem of high dimensional space, i.e., solve the optimal classification plane in high dimensional space. Thus computer vision technology and SVM are combined together for monitoring water quality abnormity. The monitoring scheme is shown in Fig. 1.

Extraction of fish motion characteristic parameter: Fish and water environment is a unified whole. Water environment can direct or indirectly affect fish population relationship, physiological characteristics and motion characteristics of fish. Motor characteristics are the most intuitive, directest and the most aging visual performance for water quality change; therefore, it is a important monitoring index in water quality abnormity research. Acquiring motion characteristics of fish rapidly and accurately becomes the indispensable step in water quality monitoring.

When computer vision is used to analyze motion characteristics of fish, the first step is to accurately detect the motion position of fish. That detection result directly affects the processing of data and accuracy of water quality abnormity determination. To date, many detection methods for moving object have been proposed in computer vision field, such as inter-frame difference method, background subtraction modeling method, optical flow and some improved algorithms. This study uses background subtraction modeling method to detect fish and then fulfills tracking and trajectory extraction by centroiding algorithm. Moving object detection and motion trajectory of single fish are shown in Fig. 2 and 3. Motion characteristic parameters of fish are further acquired based on motion trail, i.e., speed, accelerated speed, corner, distance, track, etc., to construct motion vector matrix.

Water quality monitoring modeling: To improve the accuracy and velocity of training sample and forecast sample, the motion characteristic parameters of fish extracted are preprocessed. First is smoothing, followed by solution average value of every 10 groups of data and finally the training sample set is established by normalizing data.

Establishing water quality monitoring model based on SVM is to map the training sample to a high dimensional space by some non--linear function relationship and solve optimal plane in high dimensional space to obtain decision function. Therefore, the model can be expressed as equation (6), which are merits dependent on kernel function type and its parameter as well as the penalty factor.

The steps for establishing water quality monitoring model are as follows:

1) Preprocess the motion characteristic parameter of fish acquired by computer vision technology and then establish training sample set:
2) Train the training sample set as the input of SVM;
3) Train the samples using SVM with different kernel functions and compare and pick up the optimal kernel function;
4) Pick up the optimal kernel parameter and penalty factor by making selection optimization on kernel functions and parameters using GA, PSO and grid search and comparing;
5) Confirm the optimal model making use of the kernel function and parameter acquired in step 3) and 4).

RESULTS

Experimental result and analysis: To verify the effectiveness and feasibility of the method, the following experiment is performed. Digital camera is used to acquire the videos of moving fish under normal and abnormal water environment. Each frame of the video is in size of 480*640 and in frame rate of 25 f/s.

Selection of characteristic parameter: To improve the velocity of preprocessing original data, the convergence rate of SVM and the accuracy of sample training and prediction, it is necessary to select the motion characteristic parameters extracted such as accelerated speed, speed, distance, intersection angle and track. Therefore, box plot and fractal dimensional visualization figure for motion characteristic parameters of fish are drawn, as shown in Fig. 4 and 5. Figure 4 demonstrates that, the accelerated speed, speed and

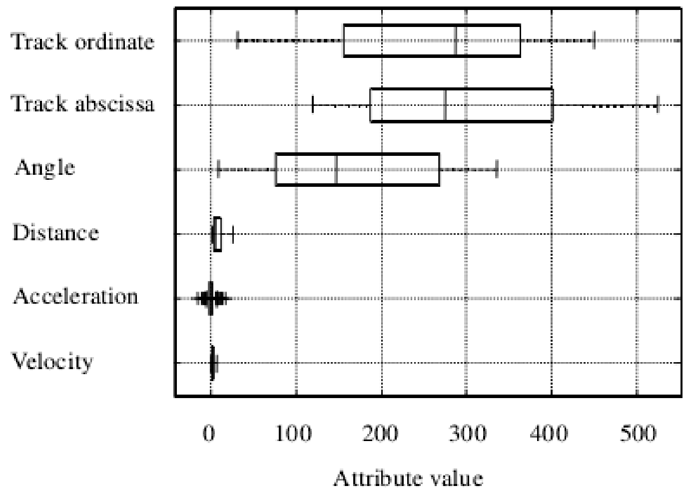

Fig. 4: Box plot of fish characteristic parameter

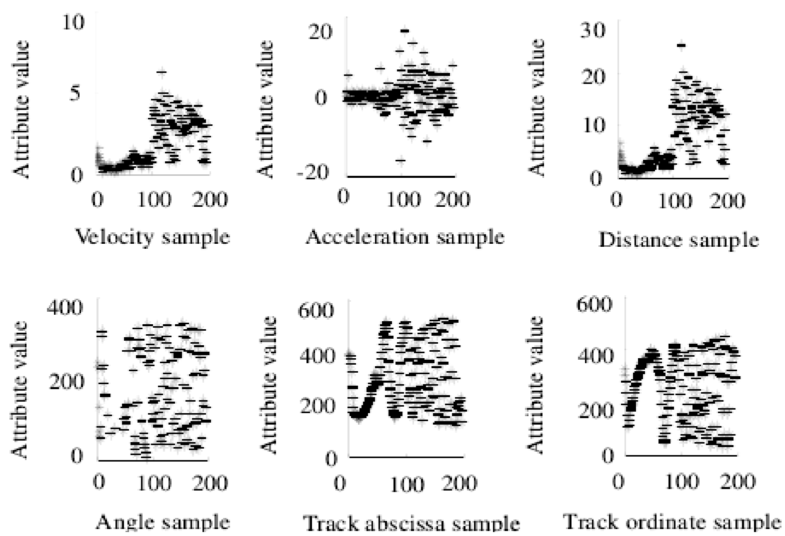

Fig. 5: Fractal dimensional visualization figure of fish characteristic parameter

distance (the height of box) distributed closely, but intersection angle and track distributed dispersed, while Fig. 5 demonstrates that, parameters of accelerated speed and distance distributed similarly. Therefore, the accelerated speed and speed were selected as the motion characteristic parameter of fish.

Preprocessing of characteristic parameter and sample set establishment: Preprocessing of characteristic parameter refers to remove the gross error in data according to 3 sigma judgment criteria, then solve the average value of every 10 groups of data and finally normalize the data to between 0 to 1.

Detailed procedures for establishing sample set are as follows:

- 1900 frames were selected from videos shot under normal and abnormal water environment, respectively for processing the original data of fish motion parameter.
- Sample set of original data is established, including 1900 training samples (950 each under normal and abnormal water environment) and test samples (90 each under normal and abnormal water environment).
- Preprocess original data and the data preprocessed includes average value and data after normalization;
- Average value sample set is established, including 180 training samples (90 each under normal and abnormal water environment).
- Normalized sample set is established, including 180 training samples (90 each under normal water and abnormal water environment).

Table 1 is the classification accuracy and classification time of different types of data. It can

Table 1: Accuracy and time of classification for different types of data

Data types	Accuracy/%	Time/s
Original data	70.3684	286.8430
Average of data	82.7778	14.61000
Normalized data	85.8333	9.703000

Table 2: Classification accuracy of different types of functions

Kernel function types	Accuracy/%
Linear	78.0556
Polynomial	49.1667
RBF	85.8333
Sigmoid	73.3333

Table 3: Classification accuracy of different types of optimization methods

Optimization method	Accuracy/%	Best C	Best σ
PSO	87.5000	1.0091900	131.803
GA	86.6667	29.712700	33.3271
Grid search	82.7778	0.0441942	181.019

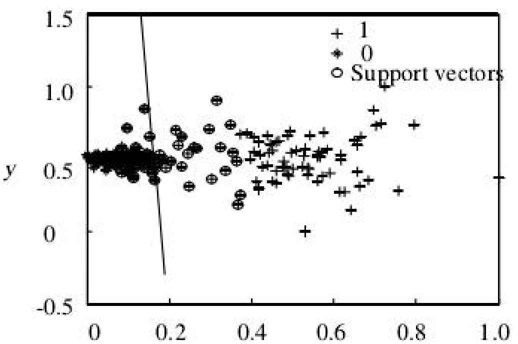

Fig. 6: Classification hyperplane

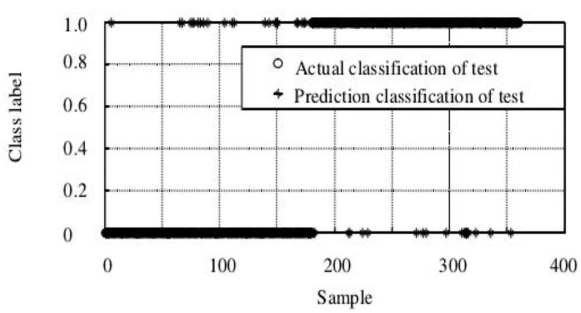

Fig. 7: Actual classification and prediction classification of test set

be known from Table 1 that, preprocessing can improve the accuracy and time for classifying training samples and forecast samples.

Selection of SVM kernel function: The common kernel function in SVM includes: linear kernel function, polynomial kernel function, radial basis function, sigmoid kernel function. The above four functions are used for classifying and comparing classification results, as shown in Table 2. It can be known from Table 2 that, classification by radial basis function is of high accuracy. Thus this study uses radial basis function.

Optimization of radical kernel parameter and penalty factor: The important parameter in radical kernel function is σ which can affect the distribution of the sample in characteristic space and thus affect VC dimension h. h further affects confidence range and empirical risk. Penalty factor C is used for regulating confidence range and empirical risk within specific space to minimize the real risk. Thus kernel parameter σ and penalty factor C are made optimization selection at the same time. This study used PSO, GA, grid search to optimize parameters and compare the classification results, as shown in Table 3. It can be known from Table 3 that, the classification accuracy of PSO is the highest. Thus this study selects PSO for optimization.

Water quality abnormity monitoring by SVM based on optimization: First is preprocess training data and then parameter C and σ was optimized using radical basis function and PSO. As parameter value is changeable, PSO is performed for several times to obtain the average value: $C = 1.5$ and $\sigma = 120$. Finally, water quality abnormity monitoring model is obtained. The classification hyperplane is shown in Fig. 6.

Water quality monitoring model that has been trained is used to forecast the data under water. There are 360 forecast samples (80 each under normal and abnormal water environment). Data that are wrongly divided can be observed from Fig. 7 actual classification and prediction classification of test set and the accuracy of forecast reaches 88.0556%.

CONCLUSION

This study establishes a water quality abnormality monitoring model based on computer vision and SVM and carries out training test on the preprocessed sample after the reasonable parameters are confirmed and the proper kernel function is selected, to achieve high classification accuracy. Thus it can be seen that, predicting the situation of water quality by analyzing fish motion characteristic parameters is rapid and accurate.

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