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USING IMAGE PROCESSING TECHNOLOGY FOR WATER QUALITY MONITORING SYSTEM

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Abstract:

As fish has been existing and adapting to the water ecological environment that it will sense physically when water quality changes. Thus, the fish responding behavior has been taken one of the methods in monitoring water quality in recent years. This study has successfully in building a water quality monitoring system by utilizing the image processing and fuzzy inference in auto-recognizing the gesture of fish. It was our first time in setting up the image background model by using W4 method, and then adopted deduction of background in recognizing the fish profile.

After finding the center-of-gravity position of fish profile, we can obtain the real time characteristic information of fish in position, speed and moving track. Finally put these information the input of fuzzy inference system, via appropriate rules bank in analyzing, the output value can be obtained. In this study, Zebra fish and Common Goldfish were adopted to be the study objects by using different into water and out of water device as well as different concentration of agent in observing the fish in response. From the result of experiment, the inferential method as proposed by this study in recognizing two kinds of fish has come to a satisfactory effect.

Keywords:

Image processing; Water quality monitoring

1. Introduction

In 1984, geneticist G.Streisinger [1] started the genetic research by utilizing Zebra fish; then, the study of fish has been applied to various fields [2]. However, along with the drastically deterioration of natural ecology and environmental pollution that more unpredictable natural and man-made calamities occurred; where, the pollution as caused by these disasters flowed into the rivers would definitely influence the water quality. In the mean time, this kind of issue has been paid attention to, which the solution has been transformed from traditional manual monitoring into nowadays automated inspection system. Thus, for the accurate inspection, it is necessary to improve the capability of fish in recognition.

For this, Loeb and Spacie [3] proposed a theory in 1994, thought water creatures have been existing in water environment for a long time, whose physical mechanism should only adapt to the current condition that any external changes occur should be able to be sensed, which made them the best environmental monitor. In view of the current environmental inspection, flea and fish have been broadly applied on the inspection of toxic water. Regarding the inspection of toxicity, it is depending upon the time in short or long, divided into the inspection of drastic toxic and chronic toxic. In the water monitoring environment, using flea in inspection can get rather good result, but however the system in execution should cope with the special purpose equipment so it can carried out normally; while, using fish in inspection would not have the same problem. The fish is fast and accurate in response, even the gene of Zebra fish is 87% similar to that of the human that when those substances harmful to human body enters into water, the fish would demonstrate the similar reaction of that of the human.

The current water quality inspection is still performed by inspector in visual check, seldom using automated device in judgment. If automated method should be applied, there are still much to be conquered technically. Lai and Chiu[4] utilized image processing in classifying the direction of gesture. The object recognition has been applied on many fields, such as the recognition of vehicle ID plate, hands, face and image etc. [5]. From the study of these items, we can understand that automation system can make problem simple and easy to be solved.

2. Study method

Two kinds of fish have been used in experiment in this article. Except the usable study method, factors are primarily the choice of fish, the setup of the background model, image processing technology and fuzzy inferences which are explained as follows:

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2.1. Introduction the fish used in the experimental

Recently, many studies have been focused on the study by utilizing the water creatures in water quality monitoring. The key factors in studying underwater creatures in monitoring water quality can be summarized into following few points: 1. a certain level of sensitivity and alertness must be well identified to the environmental change and the invasion of the contaminants; 2. the fish flock distribution should be in large amount and widely spread that easy to capture; 3. easy to raise in Lab. After referring to the related references, adopting the suggestions from the professionals, also considering the difficulties in raising, we decided to adopt Common Goldfish and Zebra fish for the experimental fishes in the study. Here is the related description to these two fishes:

Common Goldfish, in 3-5 cm length, body color uncertain, but roughly is the combination of red, orange, black and silver white. From the popular name, we know it is cheap and faded out fish due to its unfavorable color, which is mostly used to feed larger ornamental fish. The fish is tamed and easy to raise. The aquarium does not require pumping air or heating up. Usually it is favorable in swimming at the bottom layer of aquarium.

While, Zebra Danio, also named blue stripe or Indian fish, in 4.5cm long, body color in gold or silver with blue purple stripes. Easy to raise with strong productive, favorable in swimming on the upper layer of aquarium. In genetic engineering field, it is commonly used in the study of the growth of vertebrate and human genetic disease, is a typical fish category. Where, Zebra Danio is the most commonly used experimental species for standard toxicological inspection in Lab.

In the following study procedure, we utilized the above two kind of fishes in image processing and retrieved the experimental data of related gesture in characteristics to analyze its behavior.

2.2. Background model in setting up

Two step image processing has been used in this study, in which the movable pixel in the background of model has been removed. First, perform the Median Filter to all images in the film; then, use the static pixel in building initial background model. Assume V is an array which consists of N pcs continuous images; $V^i(x)$ is the images with the same pixels in the continuous film; $\sigma(x)$ and $\lambda(x)$ represent STD difference and middle value for those images at the same position respectively. Then, the values of $m(x)$ 、 $n(x)$ and $d(x)$ at x position in the background model shall be obtained from the following equation:

$$\begin{bmatrix} m(x) \\ n(x) \\ d(x) \end{bmatrix} = \begin{bmatrix} min_z\{V^z(x)\} \\ max_z\{V^z(x)\} \\ max_z\{|V^z(x)-V^{z-1}(x)|\} \end{bmatrix} \cdots\cdots\cdots (1)$$

Where $|V^z(x)-\lambda(x)| < 2*\sigma(x)$.

After this three values have been obtained, the object in front view can then be detected, whose calculation is as follows:

$$B(x) = \begin{cases} 0 \quad background & \begin{cases} (I^t(x)-m(x)) < kd(x) \\ \vee (I^t(x)-n(x)) < kd(x) \end{cases} \cdots (2) \\ 1 \quad foreground & otherwise. \end{cases}$$

$I^t(x)$ Is the pixel value of each position in the real time image; k is a proper threshold value, if k is properly set, we can obtain a better detected effect of the object in front view.

2.3. Image processing

In the generation of fish-bone chart, the study has transformed the image from RGB color model into a gray scale, which can reduce system in computing greatly.

Besides, more complicated equation or algorithm would not be required in transferring that the satisfactory effect can be achieved. Equation (3,4) is applied during the transformation from RGB color model into the gray scale; where, two different methods are:

$$(R+G+B)*1/3 = I \cdots\cdots\cdots\cdots\cdots (3)$$

R,G and B in equation (3) represents pixels in red, green and blue; while, I is the HSI Intensity of color model, i.e. gray scale of pixel. Another method is to transform RGB color model into $YCbCr$ color model; where Y is the pixel of gray scale

$$\begin{bmatrix} Y \\ Cb \\ Cr \\ 1 \end{bmatrix} = \begin{bmatrix} 0.2990 & 0.5870 & 0.1440 & 0 \\ -0.1387 & -0.3313 & 0.5000 & 128 \\ 0.5000 & -0.4187 & -0.0813 & 128 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} R \\ G \\ B \\ 1 \end{bmatrix} \quad (4)$$

Expansion and corrosion is a simplified way of image processing, which can conveniently eliminate partial image interferences, but also fill up the fine vacancy spaces.

Besides, after being Connected Component in analysis, it is able to identify the actually moving objects, while

non-targeted objects shall be eliminated. The "Connected Component" as stated above would mean a sub-set S of an image pixel consists of elements P and Q. If there exists a route completely composed by the elements of S, it is considered P and Q is "connected in the sub-set."

Regarding any element P that belongs to S, the pixel set of S as connected to is called the connected Component of S. Then, label this block and considered it an independent block as determined a moving object.

Skeletonizing is commonly used in retrieving binary images, which represent the line section of this object.

While, Skeletonizing this method could be divided into 1. Medial Axis Transformation, MAT; 2. The Peeling Approach; and 3. The Ballooning Approach etc. 3 types of algorithms.

2.4. Moving object in detecting

Basic Background Subtraction is broadly applied on the moving object in detecting; which is particularly useful to the static background. The essential procedure is to build a clean background model, with which retrieving the real time image to delete the similar area. What the left is the moving area.

$$\left| I^t(\phi) - B^t(\phi) \right| > n_c \qquad (5)$$

The and in equation (5) indicate all pixels in real time image and in background model; while, is the Threshold value after interferences being eliminated. During the process in –utilizing

$$B^{t+1}(\phi) = \alpha I^t(\phi) + (1-\alpha) B^t(\phi) \qquad (6)$$

In equation (6), α is the updating figure of background model. Analyze α from the equation, the lager the α indicates the lager the variation is, that α value would influence the background model.

2.5. Fuzzy inference

Fuzzy was originated from an article fuzzy Sets as published in the information and Control Academic Periodical by Prof. L.A. Zadeh/ Berkeley Univ. in 1965.

Computer is superior to human in its computing capability; however, to some issues, such as concept, thinking, inference and identifications etc., which is not able to be solveed by effective computation, it is inferior to human. Thus, Fuzzy theory is developed to cover the human brain in correctly judgment of fuzzy message or incomplete information which without accurate or complicated computing process.

3. Study procedure

In this chapter, we shall describe by text from image processing, characteristic value retrieving and utilizing fuzzy inference in performing the water quality in monitoring as follows separately:

Step1： Retrieve real time image via camera and transform it into gray scale to reduce the data computation.

Step2： After image being transformed into gray scale, draw 500 images out and build their background model.

Step3： Use basic background subtraction in the real time and gray scale background model and get isolated front view of fish body finally.

Step4： Adjust proper threshold value and make image in binary so that the image to be handled becomes clearer.

Step5： Utilizing expansion/ corrosion/ connected component analysis to eliminate interference and the shadows as generated by fish body.

Step6： Calculate the gravity center of the fish and generate the fish speed and track by its position.

Step7： Utilizing two aquariums in different design to analyze water flow; different agent applied shall result in different water flow distribution.

Step9： Match two kinds of fishes with different aquariums in observing the fish position, speed and tracks.

Step10： Implement the relative coefficient obtained in above step into the fuzzy inference system; we can obtain the result of fuzzy inference.

Step11： Via constant revision of fuzzy rule function and fuzzy inference until we approach the optimal target of the system.

4. Result and discussion of the experiment

Common Goldfish and Zebra Danio have been used in the experiment in this study; where the experimental aquarium was built by a glass tank of 15cm(L) x 15cm(W) x 15cm(H); 3400cc water was filled and in/out water flow was set at 3ml/sec.. Then, the experiment was performed by

different fish, different in/out exit in design and different agent concentration.

Regarding the agent in selection, Sodium dodecyl sulfate，$NaCl_2H_{25}SO_4$ was adopted, which is the primary components of detergent. SDS, commonly used as foaming agent, is usually applied in tooth paste, soap, bathing liquid, shampoo, detergent and cosmetics etc. 95% of the personal skin care products and household detergent consist of this substance.

4.1 Experiment 1: the water flow distribution in aquarium

In analyzing the water flow in aquarium, two different type devices at in/out exit were adopted. Via different water flow to analyze the resident habit of different fish can accurately understand in more detail about fish behavior.

The first water flow device in design: water inlet located at the rear right of the aquarium in image, at 5.5cm under the water. While, the water outlet is located at the front left in image, at 1cm under water, as shown in Figure. 1(a).

The 2nd type of water flow device in design: water inlet is located at the rear right of the aquarium in image, at 1am under water. While the outlet of water is located at the front left in image, at 5.5cm under water, as shown in Figure. 1(b).

Figure. 1(a).

Figure. 1(b).

Then, we shall proceed the water flow distribution test with agent in the aquarium. As the concentration of the agent shall affect the sp.gr. that we decided in performing 3 tests with different concentration of agent; while, the location of inlet/ outlet would influence the water flow distribution in aquarium.

Firstly, we made it “up in, down out” (water inlet on upper, water outlet at lower side), filled in hi and lo concentration agent. The high concentration one is as shown in Figure.2 (a); the lower concentration one is as shown in Figure. 2(b). The water flow distribution due to Hi/Lo concentration of agent can then be observed when in comparing the relationship of sp.wt. of agent vs. water.

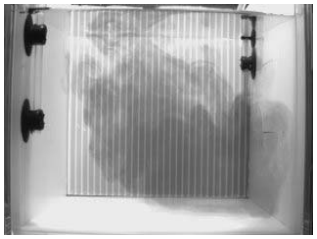

Figure. 2(a).

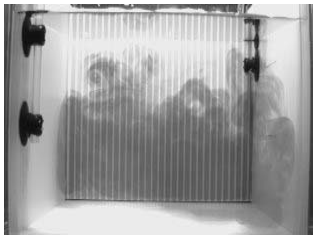

Figure. 2(b).

In the mean time, another arrangement of own in, up out? (inlet at lower and outlet at upper) was adopted in performing the experiment by filling different concentration of agent; where, the high concentration one is as shown in Figure.3(a), and lower concentration one is as shown in Figure.3(b). In comparison of the result of water flow distribution in above experiment, we can observe clearly different inlet/ outlet location would influence the agent distribution in aquarium as well.

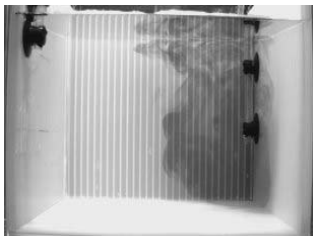

Figure. 3(a).

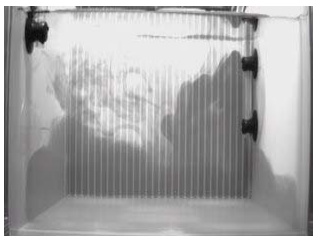

Figure. 3(b).

4.2 Experiment 2: building the background model and front view in detecting

In this experiment, we shall verify the sturdiness of the background model as built in this study. It was our first time in setting up the image background model by using W^4 method, and then adopted deduction of background in recognizing the fish profile. Figure.4 (a) is the result of background as trained; while, Figure.4 (b) is the font view after image being subtracted.

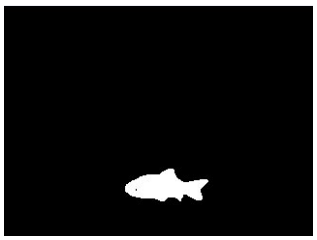

Figure. 4(a).

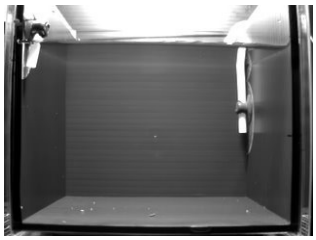

Figure. 4(b).

4.3 Experiment 3: Utilizing image processing in performing the experiment of fish real time position, speed and tacks.

The gravity center of the fish can then be obtained from the pixel algorithm; which is defined the position of fish. Afterwards, the statistics of speed and track can be done. Figure.5 (a-b) and Figure.6(a-b) are the tracking position of Common Goldfish and Zebra Danio, respectively.

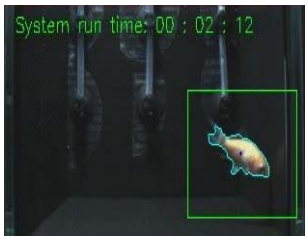

Figure. 5(a).

Figure. 5(b).

Figure. 6(a).

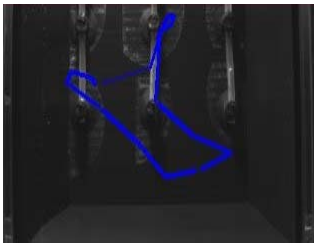

Figure. 6(b).

4.4 Experiment 4: analysis of polluted agent vs. fish position, speed and tracks.

After position, speed and track data of the two fishes have been obtained from the experiment 3, this experiment shall perform the influence of different fish vs. different concentration of agent.

First, the Common Goldfish and Zebra Danio were put an aquarium with Up out, down in inlet/ outlet arrangement, filled in two different concentration agent, and record the position, speed and track of the fishes. From Figure.7(a-b) and experimental statistical data, we can clearly observe the Common Goldfish would swim and move to the lower concentration agent zone when sensed the agent.

Besides, we also observed the fishes alter their swimming direction more frequently, seemed unusually uneasy and irritable.

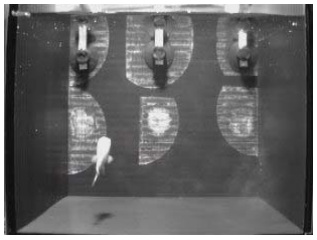

Figure. 7(a).

Figure. 7(b).

Then, we took record of Zebra Danio according to the same experiment step of its position, speed and tracks. From Figure.8(a-b) and experimental data, we can also observe clearly the fish alters its swimming direction more frequently when agent was filled in.

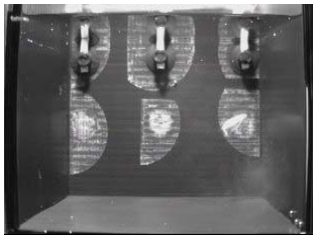

Figure. 8(a).

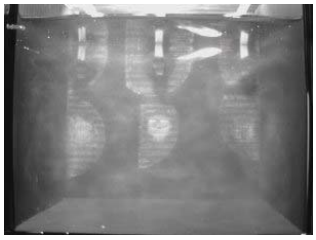

Figure. 8(b).

5. Conclusion

In this study, the image processing technology and fuzzy inference technology have been successfully applied on the study of the fish body in recognizing its gestures.

Two kinds of different fishes in appearance were selected to fit for the aquarium with different water inlet/ outlet in design as well as with different concentration of agent in experiment. The result has verified the water quality inspection system based on image processing as developed by our research institute comes with satisfactory effect. It is concluded that we can understand the water contaminated condition by observing the fish behavior in rather short period of time.

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