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Study on the Image Treatment of Ultrasonic Cavitation Bubbles

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Abstract

Ultrasound is widely used in many ways. The instant effect of ultrasonic-cavitation bubbles' collapse is an indispensable condition for a fine effect of ultrasonic applications. Therefore, it is necessary to do some research on the parameters of ultrasonic cavitation bubbles. As a non-contact measurement method, image method is more simple and accurate. This paper based on the algorithm principle commonly used in digital image processing techniques, focus on the gray level transformation of cavitation bubble, including gray linear transformation, logarithmic transformation and gamma transformation, after each kind of the transform method under different parameters, compare the effects and came out the gamma transformation following the equation is the best method used in improve pixel brightness.

Keywords: Ultrasonic-cavitation, bubble measurement, image processing, gray level transformation.

1. Introduction

With the advance of science technology, ultrasound have been used in sorts of areas. Ultrasonic cavitation will conduct a series of physical and chemical reactions, widely used in the fields of urban and industrial wastewater treatment, ultrasonic cleaning, sound chemical reaction, and medicine[1-2]. Extreme effects like high temperature and jet impinging are produced when the cavitation bubbles collapse. It's necessary to study on the transformation of ultrasonic-cavitation bubbles.

Measurement of micro size bubble distribution in the water is acoustic resonance reflection method [3-4] and optical photography method [5-7]. Rayleigh [8] first came up with dynamic model of ideal spherical cavitation bubbles. Based on Payleigh's achievements, Kyuichi Yasui took into account the evaporation and condensation of water vapor inside and outside the bubble, obtained the equations of motion of the bubble [9]. Qian Menglu and Cheng Qian [10], by changing the driving pressure, studied dynamic characteristics of cavitation bubbles, discussed the energy concentration effect of cavitation bubbles in collapse stage.

This paper uses ultrasonic-cavitation bubble shooting device to capture cavitation bubble image, and the image was processed by gray linear transformation, gray transform, gamma transform methods, for the best image processing method.

2. Materials and methods

2.1. Experimental apparatus

Fig. 1 is the schematic of the ultrasonic-cavitation bubbles gather device. The glass container is filled with a certain amount of de ionized water, and the cavitation bubbles are generated by the ultrasonic

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probe in the glass container. Ultrasonic-cavitation generator (GM-1200D, Nanjing Shun Ma instrument and Equipment Co., Ltd.) generates cavitation bubbles, rated power of 1200W, frequency 15KHz. YAG dual-pulse laser. The two pulse laser produce laser, through the beam combiner from an outlet of the optical path, strict spatial coincidence between emitted and through the light guide arm and light sheet system. As a result, pulse of illumination light source. The thickness of the light source is about 1mm, and the light plane is parallel to the axis of the circular tube. The digital camera captures the image through the external trigger, and real-time transmits the captured image data to the computer in through the image acquisition board.

The trigger signal is generated by the synchronization controller to keep the complete synchronization with the pulse laser. Synchronization controller can use the internal time base, generates a periodic pulse trigger signal, after some delay channel, also produce multiple passes over the delay trigger signal, used to control the laser, digital camera and image acquisition board, make them work in Strictly synchronous signal base.

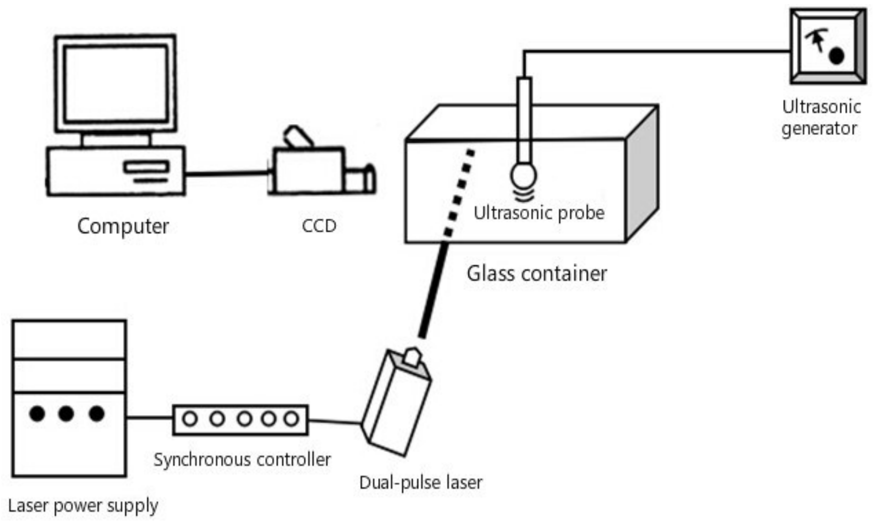


Fig.1 Schematic of the ultrasonic-cavitation bubbles gather device

2.2. Treatment methods

For images saved by computer, use a variety of algorithms to modify and enhance the image, in order to obtain better image appearance, to output a better image effect, in order to facilitate further observation and processing, can also be fundamental research for image analysis. Image analysis is input by image through digital processing, the output usually is no longer a digital image, but a series target image features associated to object, such as length, color, curvature and number, etc. Digital image through the point of operation and the gray scale transformation can effectively improve the appearance of the image, to some extent; achieve the image's gray level normalization.

3. Results and discussion

Fig.2 shows the captured ultrasonic-cavitation bubble image by the experimental equipment that can be clearly seen by the laser exposure in water refraction and scattering and other factors, led to lack of brightness, so it can increase the brightness of the bubble image by enhanced the gray levels of the bubble.

The gray value is to change the value of each pixel point. Assume r and S is the input image *f(x,y)* and the output image *g(x,y)* as an arbitrary point gray value, gray transformation using the following relation [5]:

$$s=T(r) \tag{1}$$

In the formula, T is the computation operator of the transformation, illustrate the gray level mapping relations between the original image and output image. Mapping relations includes linear operator and nonlinear operator. Generally we used linear transformation with gray level, as for gray level logarithmic transformation and Gamma transformation belong to nonlinear transformation.

The following three methods use conversion processing with the image of the ultrasonic-cavitation bubbles. Each method compares the vary parameter to get every best processing result. And then through the analysis of effect image after various methods, select the best way to deal with them.

Fig.2 The ultrasonic-cavitation bubbles

3.1. Gray linear transformation

Linear gray level transformation function is a linear function of one dimension[11-15]:

$$D_B=f(D_A)=f_A \times D_A+f_B \tag{2}$$

Where D_B *is* gray value of output image, f_A is slope of linear function, f_B is linear intercept function in y axis, D_A is gray value of input image.

When $f_A>1$,The contrast of the output image will be increased; When $f_A<1$,The contrast of the output image will be decreased; When $f_A=1$ and $f_B \neq 0$ operation can only make gray value of all pixels in the image move up or down, the effect is to change the entire image to lighter or darker; When $f_A=1$ and $f_B=0$ the output image is the same as the input image; When $f_A=-1$ and $f_B=255$ The gray level of the output image is just reverse, gray inversion processing is applied to enhanced details which are lighter in the dark image.

Fig.3 is a schematic diagram of the partial gray linear transformation. The transformation of each gray level according to different functions is clearly expressed. When capturing cavitation bubbles, although the laser intensity is very strong, but the intensity of the laser intensity in the ionized water is exponential decay, and after refraction and scattering of the loss, the final light reaches CCD light intensity is very weak, so the bubble image is very dark, we must increase its contrast and brightness. The results are as shown in Fig.4, with the increase of brightness, contrast, inversing image display, and increasing contrast and brightness together.

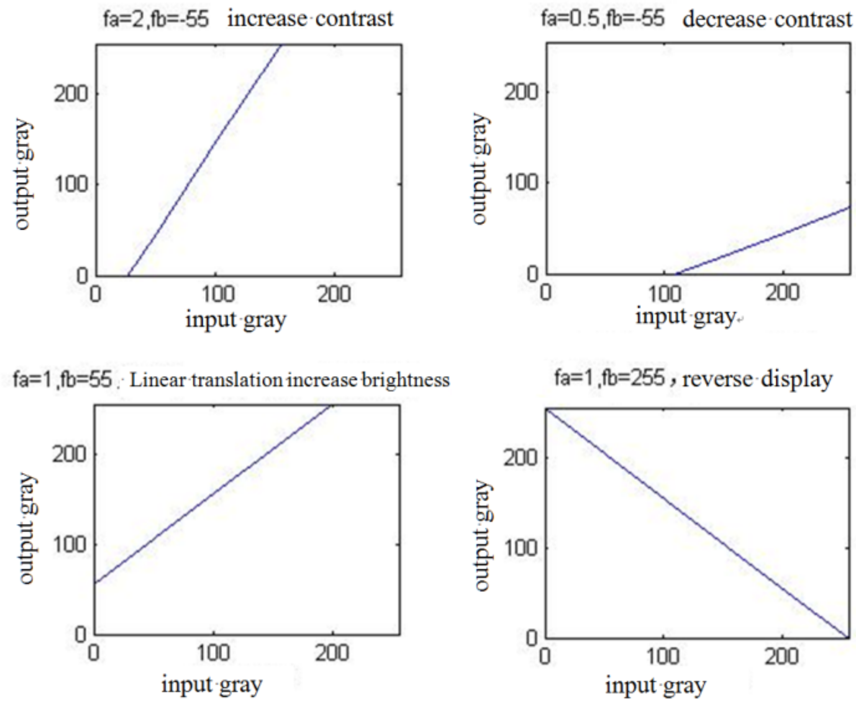
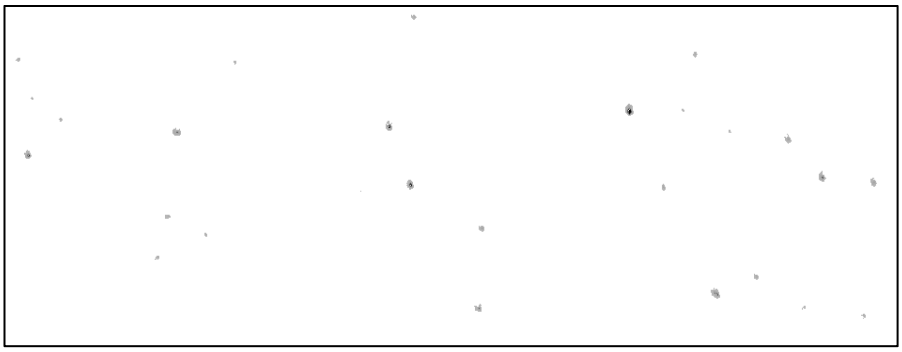


Fig.3 The linear transformation

Compared with the initial image, after four different linear changes, the overall image brightness increased, although the bubble brightness has increased, the background brightness is also increased; resulting in visual effect is not obvious. Background color would increase if you increase the brightness, leading to the observed bubble visual effect decreased. Increasing the contrast degree can improve the bubbles' overall gray level and enhance the brightness of lower gray pixel, but the effect of higher gray pixel's enhancement is weaker. Reverse the image, which is changing the color of background to bright and bubble's to dark. Because the bubble is small, the background color is very high; the brightness of the smaller part is difficult to distinguish the outline and size by our naked eye. Increasing the brightness and contrast together, the bubble image can be slightly better than increasing the brightness or the contrast alone, but the effect is still not ideal.

(a) Increase brightness

(b) Increase contrast



(c) Image inversion

(d) Increase the contrast and brightness together

Fig.4 After different linear transformation

3.2. Gray scale logarithmic transformation

The expression for the logarithmic transformation is:

$$t=c\times\log(1+s) \tag{3}$$

where c is ratio constant, s is initial image gray value, t is transformed target gray value.

Because the Matlab logarithmic transformation can only deal with the double precision data matrix, we need to transform it. In order to achieve the purpose of processing, the gray level 0~255 one by one corresponds to the 0~1, that is, image normalization. As shown in Fig.5. When the value of the function argument is low, that is, when the gray value is low, the curve slope is larger; on the contrary, the curve slope is smaller, so it can be known that the gray level enhancement is more obvious. And its scale ratio constant C and can control the change range, the greater the value of C, the greater the curve amplitude change, that is, the lower the gray level pixel, the brightness increase will be more obvious.

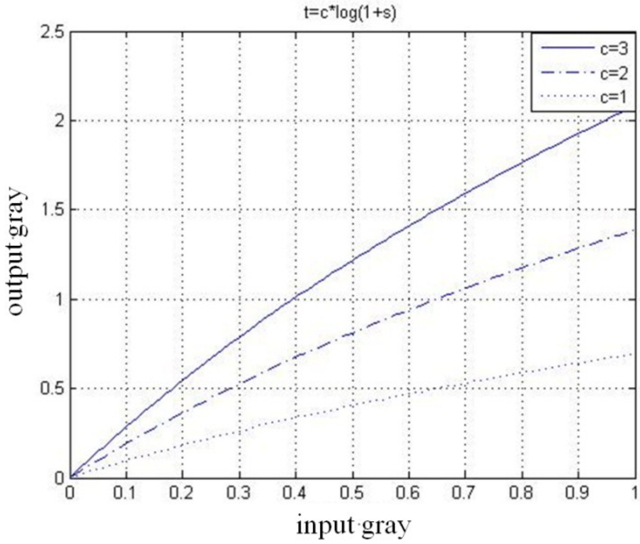


Fig.5 The logarithmic transformation

According to Fig.5 shows the different scale proportionality constant c value and the original image of different gray logarithm transformation. When the value of the constant c is greater, enhanced low gray part of the effect more obvious, the overall picture is better. Fig.6 is the output of the gray scale logarithmic constant *c*=3, the overall effect is the best.

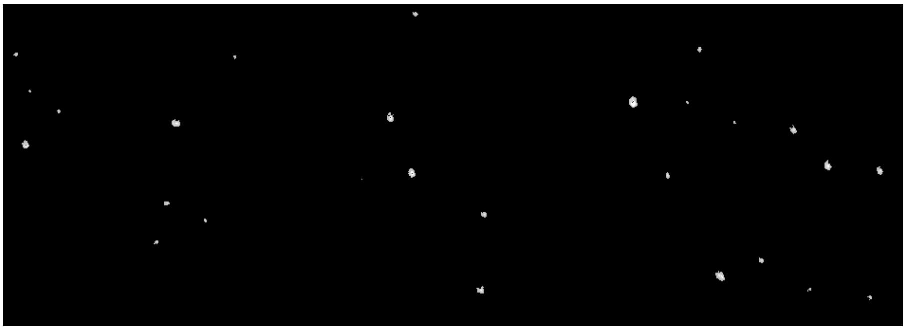


Fig.6 After logarithmic transformation (*c*=3)

3.3 Gamma transformation

The gamma transform, also known as the exponential transformation, is another commonly used to distinguish the logarithmic transformation of the gray nonlinear transformation, the transformation function is:

$$y=(x+esp)^{\gamma} \quad (4)$$

where the range of x and y is 0~1, *esp* iscompensation coefficient, γ is gamma coefficient.

Gamma transform is different from linear change and logarithm transform. According to different values of γ, it can focus on strengthening the gray value of a gray range. The value of γ determines the way of gray level mapping between input and output. For the image of the cavitation bubble to be processed, it is decided to enhance the shadow area of the bubble or the highlight area of the bubble. When $\gamma>1$, the region of high gray value is enhanced, when $\gamma<1$, the region of low gray value is enhanced, when $\gamma=1$, the image gray value does not change. The schematic diagram of the gamma transformation is shown in Fig.7. When it is carried out, it usually transform the gray scale range of 0~255 to 0~1.

In order to enhance the gray value of the bubble shadow region, the lower the gamma value is, the better the effect is, so according to the three kinds of conditions that γ=0.04, γ=0.2 and γ=0.4, it is transformed (among them *esp*=0), and the conversion effect is shown in Fig.8. The best one, the bubble under the dark brightness was improved.

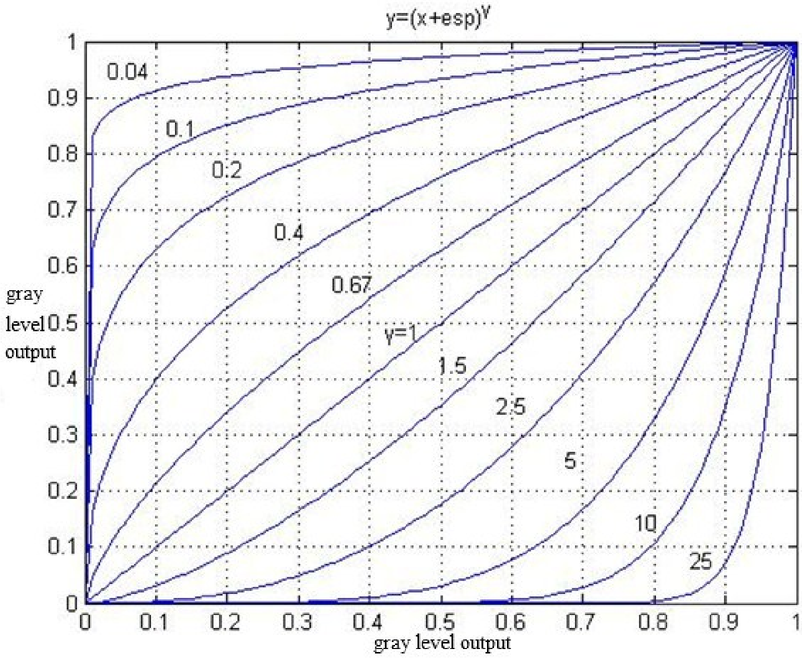


Fig.7 The gamma transformation

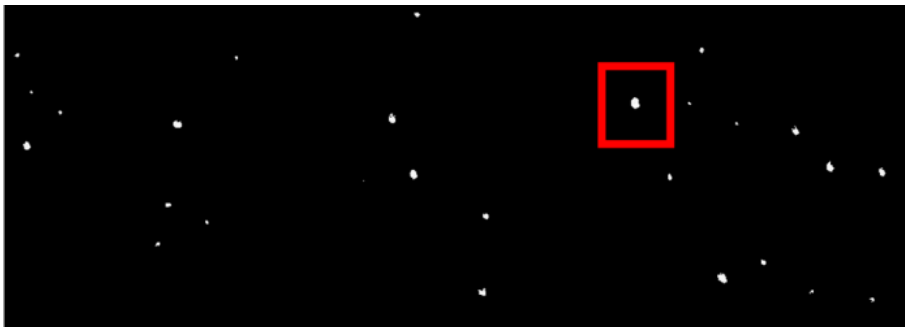
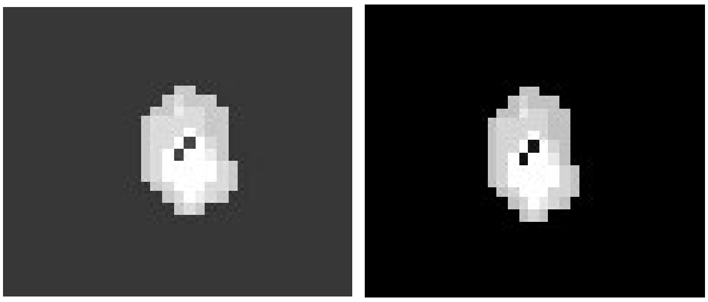


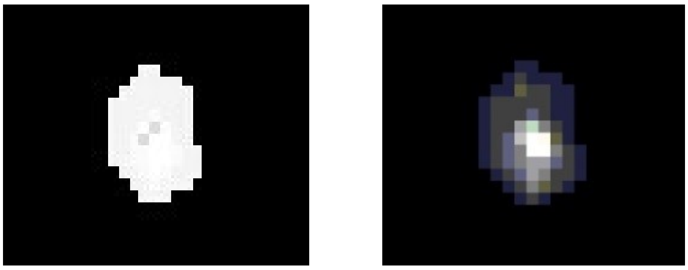
Fig.8 The gamma transformation (γ=0.04)

3.4. Comparison of gray level transformation

In order to direct analysis effect of which kinds of transformation can reflect the actual situation better, select the condition that can respectively maximally enhance each transformation's contrast of bubble shadow region, then a bubble (as shown in Fig.8), the contrast effect as shown in Fig9. Compare the original image; we will see every transform method make the shadow of bubble's gray level higher. There're some black points led to a image detail missing because of linear transformation and logarithmic transformation make the high brightness area in center of bubble has a gray value more than 255. So, as a result, the gamma transformations have more improvement in gray level, not even mention no image detail missing. Gray level transformation based on point operation, so image will keep the original features and shape, so it is necessary to highlight the image. All in all, Gamma transformation that following the equation γ=0.4 is the best way to do the gray level transformation.



(a) increase contrast and brightness　　(b) logarithmic transformation



(c) gamma transformation　　(d) original image

Fig.9 The contrast of different transform methods

4. Conclusions

Based on the original ultrasonic-cavitation bubble image captured by ultrasonic-cavitation bubbles gather device, through the gray level transformation, we will see the effect diagram of linear transformation, logarithmic transformation, gamma transformation respectively that in different parameters. After the comparison of all transformation, the gamma transformation is the best method to deal with ultrasonic-cavition bubbles.

Acknowledgements

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