Study on image quality Control Method based on Gaussian Noise

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Abstract. At present, various image quality evaluation algorithms emerge in endlessly. The establishment of these algorithms, the performance evaluation of the system and the accuracy of evaluation results all need to be based on images of different quality as reference standards. This paper selects the peak signal-to-noise ratio as the characteristic parameter to measure whether the image quality changes, and uses the control image quality parameter to control the image quality. The experimental results show that the model can quickly and accurately obtain a large number of images with different distortion degrees, and control the image quality.

1. Introduction

Image quality is the evaluation result based on people's subjective feelings. When transmitting and processing digital images, due to the influence of processing methods, imaging process or transmission media, it will lead to different types and degrees of distortion of images and affect the visual effect of images. Image quality evaluation mainly analyzes and studies the characteristics of the image, and then evaluates the quality of the image, that is, the degree of image distortion.

To solve this problem, this paper studies the evaluation parameters of image quality, analyzes the conditions affecting the evaluation parameters, and completes the control of image quality by changing the conditions controlling the evaluation parameters, so as to obtain images of different quality.

2. Image quality evaluation system

2.1. Image quality evaluation method

Image quality evaluation plays a very important role in the analysis and comparison of evaluation algorithms and the performance evaluation of the system. There are two most common image quality evaluation methods: subjective image quality evaluation method and objective image quality evaluation method¹.

Subjective image quality evaluation method is based on everyone's experience and understanding of the image, objectively score the image under the specified evaluation scale, and then weighted average these scores to obtain the evaluation results. Since the final receiver of image information is human, the subjective evaluation method is the most reasonable image quality evaluation method². Although the subjective evaluation method is more intuitive and consistent with the human eye's cognition of the image, it requires repeated experiments to obtain the ideal results through this
method, which requires a large amount of human and material resources, takes a long time, and is quite troublesome to operate. Therefore, an image evaluation model rarely uses subjective quality evaluation, but because of its high accuracy, it can be the most standard to verify the effectiveness of objective quality evaluation methods.

Objective image quality evaluation method is based on the principle of imitating human visual system to establish a mathematical model to evaluate the image quality. It can be divided into three kinds: full reference, semi reference and no reference image quality evaluation. The full reference image quality evaluation method calculates the quality evaluation parameters such as peak signal-to-noise ratio (PSNR) and mean square error (MSE) according to all the information of the original image to judge the image quality; The semi reference method uses the limited part of the reference image information that can be obtained as a reference. The non reference method can not obtain any information of the original image, and can only be judged directly according to the characteristics of the image. The most common method is to evaluate the quality based on the model based on a large number of samples such as neural network[3].

2.2. Image quality evaluation parameters

The subjective method of image quality evaluation requires a large number of experiments, takes a long time, is vulnerable to the influence of the environment and observers, and cannot obtain stable evaluation results[4]. The semi reference and non reference image quality evaluation methods in the objective image quality evaluation methods require a large number of test samples and are highly dependent on the evaluation algorithm. However, the current algorithms emerge in endlessly and the quality is uneven, which does not lead to different evaluation results for the same evaluation algorithm and can not obtain unified and stable evaluation results[5].

Based on the analysis of the characteristics of different image quality evaluation methods, the most objective and stable method to characterize the image quality is the full reference image quality evaluation method. This method measures the image quality level by calculating the parameters representing the image quality, which can reflect the image quality from different angles. It has specific mathematical formula, can obtain stable evaluation results, and is not affected by algorithm model, test environment and test personnel. Therefore, it is the most representative[6].

Image quality evaluation parameters include peak signal-to-noise ratio (PSNR), mean square error (MSE), structural similarity (SSIM), resolution, etc.[7]. Peak signal-to-noise ratio (PSNR) is a common index to measure image quality. It is the logarithm of the mean square error between the distorted image and the original image relative to the square of the maximum signal value. The calculation formula of peak signal-to-noise ratio is as follows[8]:

\[
PSNR = 10 \log \frac{L^2}{MSE}
\]

(2)

Where \(R(m, n)\) and \(I(m, n)\) respectively represent the gray value of the original image and the distorted image at the spatial position \((m, n)\). For an 8-bit grayscale image, the peak signal \(L = 255\). The relationship between other image quality evaluation parameters and image quality is shown in Table 1:
Table 1. Image quality evaluation parameter.

| Image quality evaluation parameter | definition | principle |
|------------------------------------|------------|-----------|
| MSE                                | Mean square value of pixel difference between distorted image and original image | Based on pixel error statistics |
| SSIM                               | Similarity of structure information between distorted image and reference image | Based on the structure information between image pixels |
| Resolution                         | The number of pixels the image contains | Based on the number of image pixels |
| Dynamic                            | Ratio of maximum value to minimum value of image gray value | Range based on pixel gray value |

3. Image quality control method based on Gaussian noise

There are many kinds of image quality evaluation parameters. Different parameters are based on different evaluation principles and represent the image quality[9]. Therefore, these parameters have different sensitivity to different distortion types. Only by finding the distortion types that directly affect the parameters according to the calculation principle and mathematical model of image quality evaluation parameters, can the calculation results of parameters be effectively adjusted, so as to achieve the purpose of controlling image quality.

As one of the most direct evaluation parameters of image quality, the peak signal-to-noise ratio can directly and quickly reflect the image quality. The better the quality, the lower the peak signal-to-noise ratio, the worse the image quality, and the higher the peak signal-to-noise ratio[10]. Therefore, in this paper, the peak signal-to-noise ratio is selected as the characteristic parameter to measure whether the image quality changes. By adding different degrees of Gaussian noise to the image, the image quality is affected, so as to obtain a series of images with different peak signal-to-noise ratio values. The image quality is controlled by controlling the image quality parameters. The specific implementation process is shown in Figure 1.

![Figure 1. Flow chart of image quality control method](image)

3.1. Addition of image Gaussian noise

The noise in the image can come from all links in the image generation link, including image acquisition process, image transmission process and image processing process. According to the probability distribution of the noise itself, it can usually be divided into Gaussian noise, impulse noise, exponential noise, uniform noise and other forms. Gaussian noise is the most common of all noises. It exists in various circuits and noises caused by high temperature, and its distribution conforms to the law of normal distribution. Therefore, this paper chooses to add different degrees of Gaussian noise to the image to affect the image quality, so as to realize the control of image quality.
The most common method to obtain images with Gaussian noise in the laboratory is to use the Gaussian noise addition algorithm in MATLAB. All kinds of noise can be added by using the imnoise function, and Gaussian noise can be added by using the "Gaussian" parameter. The mean and variance parameters in "Gaussian" can be changed to add different degrees of Gaussian noise to the image.

3.2. Relationship between peak signal-to-noise ratio and Gaussian noise

Peak signal-to-noise ratio reflects the relationship between image useful signal and noise. Therefore, this parameter is very sensitive to the change of noise. The change of noise in the image will directly cause the change of the value of peak signal-to-noise ratio of image quality parameter. The relationship diagram is as follows:

Figure 2. Relationship between peak signal-to-noise ratio and Gaussian noise

The control model has two inputs, which are the mean x and variance y of the key parameters adding Gaussian noise, and one output is the peak signal-to-noise ratio PSNR. Therefore, the model can be used to control the output PSNR by changing the input variables (x, y).

4. Experimental results and analysis

The use of sections to divide the text of the paper is optional and left as a decision for the author. Where the author wishes to divide the paper into sections the formatting shown in table 2 should be used.

4.1. Establishment of control model

Based on the above analysis, the model has two inputs and one output, and the function defining the model is \( P = P(x, y) \). Where x and y represent the mean and variance in "Gaussian", and the common range of peak signal-to-noise ratio of image is 30dB ~ 70dB. When the peak signal-to-noise ratio is 30dB, it means that the image quality is very poor and cannot meet the use requirements. When the peak signal-to-noise ratio is 70dB, it means that the image quality is good. Therefore, in order to cover the range of peak signal-to-noise ratio, the value range of output peak signal-to-noise ratio is determined as: 30dB < \( P < 70dB \). In order to ensure that the peak signal-to-noise ratio of the model output can cover this range, it is necessary to assign initial values to the two parameters. After calculation, it can be seen that the mean value is 0.01 ~ 0.4 and the variance is 0.010 ~ 0.035, which can meet the requirements.

Using MATLAB to add Gaussian noise to the image, the initial value of the mean is 0.01, the step is 0.01, and the maximum value is 0.4; The initial value of variance is 0.011, the step is 0.001, and the maximum value is 0.035. Using these 1000 data points, the relationship model between Gaussian noise and peak signal-to-noise ratio is established.

According to the above analysis, in the model \( P = P(x, y) \), 0.01 < x < 0.4; 0.01 < y < 0.03, take Figure 3 as the original figure for the experiment.
4.2. The simulation of control model

According to the above test requirements, determine the input and output of the model, and obtain the relationship between Gaussian noise and peak signal-to-noise ratio, as shown in Figure 4.

The functional relationship is as follows:

\[
p(x, y) = 34.4 + 111x - 1182y + 283.4x^2 - 9784xy + 87580y^2 - 13300x^2y + 377600xy - 2831000y^3 + 193300x^2y^2 - 4960000xy^3 + 32830000y^4
\]

The adjusted R-square of the fitted function is 0.9997 and the root mean square error is 0.16db, which can fully meet the interval 1dB of different peak signal-to-noise ratio changes in the map library.

The obtained control model is verified. The mean and variance parameters of peak signal-to-noise ratio other than simulation data are added to the original image by MATLAB. The peak signal-to-noise ratio is calculated by MATLAB and compared with the peak signal-to-noise ratio calculated by the model. In this paper, the points within the parameter range (0.025, 0.0115), (0.075, 0.0155), (0.125, 0.0205), (0.175, 0.0255), (0.225, 0.0275), (0.275, 0.305), (0.375, 0.0325) are selected as the verification points. The peak signal-to-noise ratio coverage of the verification points ranges from 30dB to 70dB. The calculation results are shown in the table:
Table 2. Calculation results of relative error

| Verification point | Exact value (dB) | Value of the model (dB) | relative error |
|--------------------|-----------------|-------------------------|----------------|
| (0.025, 0.0115)    | 29.6810         | 29.7541                 | 0.25%          |
| (0.075, 0.0155)    | 32.6397         | 32.6036                 | 0.11%          |
| (0.125, 0.0205)    | 35.2858         | 35.4426                 | 0.44%          |
| (0.175, 0.0225)    | 38.9285         | 38.7419                 | 0.48%          |
| (0.225, 0.0270)    | 41.6117         | 41.6503                 | 0.09%          |
| (0.275, 0.305)     | 44.6791         | 44.4181                 | 0.58%          |
| (0.315, 0.0335)    | 47.4421         | 46.6596                 | 1.65%          |
| (0.350, 0.0245)    | 51.0362         | 51.2460                 | 4.51%          |
| (0.355, 0.0235)    | 60.0505         | 60.5057                 | 0.75%          |
| (0.390, 0.0205)    | 70.7994         | 71.3139                 | 0.73%          |

According to the calculation results, the relative errors are less than 5%, and the difference between the peak signal-to-noise ratio calculated by the model and the actual value is far less than 1 dB. In the distorted image in the library, the change of peak signal-to-noise ratio value is far greater than 1 dB, and the change of peak signal-to-noise ratio recognized by human eyes is also greater than 1 dB. Therefore, the fitting effect of the model is good, and can reflect the relationship between peak signal-to-noise ratio control parameters and peak signal-to-noise ratio value.

5. Conclusion
At present, the establishment of various image quality evaluation algorithms, the performance evaluation of the system and the accuracy of evaluation results need to be based on images of different quality as reference standards. Therefore, it is of great significance to quickly obtain images of different quality. By studying the evaluation parameters of image quality and analyzing the conditions affecting the evaluation parameters, the relationship model between peak signal-to-noise ratio parameters and peak signal-to-noise ratio is obtained. By changing the input parameters, the model can quickly and accurately obtain a large number of images with different distortion degrees, so as to obtain the expected quality images and complete the control of image quality. In the future research of image quality control methods, the image quality control model can be constructed based on different image distortion types and image quality evaluation parameters, and more targeted image control methods can be obtained.

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