An image processing toolbox based on MATLAB GUI

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Abstract. Our research realizes the basic processing of images based on MATLAB GUI. The functions include image reading, storage, display, adding noise, denoising, image enhancement, edge detection, image segmentation, discrete Fourier transform, wavelet transform, feature extraction, target recognition, color image processing, etc. At the same time, the image can be stylized and different filter processing can be carried out on the image.

1. Introduction
Graphic user interface refers to the computer operation user interface displayed in a graphic way, and is the dialogue interface between the computer and its users[1]. It is an important part of a computer system with the characteristics of man-machine interaction, aesthetics, practicability and technology. In recent years, with the development of Internet and communication technology, GUI has become a bridge for data exchange between users and software and hardware systems, with rapid development [2].

Digital image processing technology is to use computers to process images, including denoising, enhancement, segmentation, feature extraction and so on. The basic features are large amount of processing information, wide frequency band occupied, large correlation of each pixel, unable to reproduce all information, and greatly affected by human phonemes. In recent years. This technology has developed rapidly and been widely used at home and abroad, but it is not mature in terms of its discipline construction[3].

Based on the MATLAB GUI interface, we made an image processing toolkit. We read, store, display, add noise, denoise, enhance, edge detection, image segmentation and so on. At the same time, we process the image to present different filter effects.

2. Method
Our research has designed a total of 9 first-level menu bars, namely: file, grayscale, image transformation, noise addition, denoising, image enhancement, edge detection, image segmentation, image stylization, each of which is a first-level menu. The corresponding secondary menu bar, as shown in figure 1 below.
2.1. Interface design
When designing the interface, we hide the coordinate system, that is, set the axes to make it invisible. The initial interface diagram is as follows.

2.2. Loading, saving and graying
When opening the image, it is realized by calling the MATLAB toolbox system function uigetfile. The function returns the file name and path of the selected file. The image file can be further read through the file name and path. The processed image is stored in the variable I_now. When saving the image, you only need to save the variable as an image file. The operation of saving a file is similar to the operation of opening a file. It is realized by the MATLAB toolbox system function uiputfile. The function return value is the file name and path of the file to be saved.

Grayscale. In the RGB model, if R=G=B, the color represents a grayscale color. The value of R=G=B is called the grayscale value. Therefore, each pixel of the grayscale image only needs one byte to store the gray value (also known as the intensity value, the brightness value), and the gray range is 0-255.
MATLAB call function: `I_gray=rgb2gray(I)`.

The gray scale calculation formula is as follows.

\[
Gray = \frac{R^2 + (1.5G)^2 + (0.6B)^2} {1 + 1.5^2 + 0.6^2}
\]  

(1)

### 2.3. Geometric transformation

To realize image rotation, you can use MATLAB's built-in function `imrotate`. There are three interpolation methods (methods): nearest (nearest neighbor), bilinear (bilinear), bicubic (bicubic), and the syntax format is `B=imrotate(A, angle, method)`. In order to make the returned image the same size as the original image, the following format can be used `B=imrotate(A, angle, method, 'crop')`.

Its function is to cut the rotated image by specifying the crop parameter, rotate the image by an angle, and then return to the middle part of the same size as the original image.

The horizontal and vertical flipping is the effect of the image after the left and right mirror processing, and the upper and lower mirror processing. This operation can be used repeatedly, that is, the image that has been flipped horizontally can be flipped vertically.

### 2.4. DFT/IDFT, DCT/IDCT

Discrete Fourier Transform (DFT) is a discrete form of Fourier Transform in both the time domain and the frequency domain. It transforms the sampling of time-domain signals into samples in the discrete-time Fourier transform (DTFT) frequency domain. In form, the sequences at both ends of the transform (time domain and frequency domain) are of finite length, but in fact these two sets of sequences should be regarded as the main value sequences of discrete periodic signals.

In the Fourier series expansion, if the function is symmetrical to the origin, there will only be a cosine function term in the series. Inspired by this phenomenon, people proposed another image transformation method-Discrete Cosine Transform (DCT). Since the discrete cosine transform has the important visual information of the image concentrated in a small part of the coefficients of the transform, the DCT transform is very useful in image compression and is the basis of the JPEG (Joint Photographic Expert Group) algorithm. The formula is as follows.

\[
F(u) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} f(n) W_n^u, 0 \leq u \leq N-1
\]

\[
W_n = \exp[-j2\pi / N]
\]

(2)

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\[
F(u, v) = \sum_{m=0}^{N-1} \sum_{n=0}^{N-1} f(m, n) a(m, n; u, v)
\]

(3)

\[
f(m, n) = \sum_{u=0}^{N-1} \sum_{v=0}^{N-1} F(u, v) a(m, n; u, v)
\]

(4)

### 2.5. Wavelet Transform

Wavelet analysis is a mathematical tool developed in recent years and quickly applied to many fields such as image processing and signal analysis. It is a major breakthrough after the analysis of Joseph Fourier more than one hundred years ago[5]. It has had a strong impact on both the ancient natural disciplines and the emerging high-tech applied disciplines. Wavelet transform is a commonly used image processing method in digital image processing. For N×N images, the wavelet decomposition process is shown in the figure below. Among them, LL1 is the low-frequency component, HL1 is the horizontal high-frequency component, LH1 is the vertical high-frequency component, and HH1 is the diagonal.
high-frequency component.

![Wavelet decomposition process diagram](image)

Figure 3 Wavelet decomposition process diagram

2.6. Noise addition and denoising

For image noise adding and denoising, color images and grayscale images use similar algorithms. The implementation of color image noise adding and denoising is to add noise and denoise separately for each component of RGB, and then after sub-item connection, a color image is formed. Here, only the grayscale image is added and denoised. When adding noise, by calling `imnoise` in the MATLAB image processing toolbox, the input parameters of this function can be divided into two parts, the first part is the original image data, and the second part is the type of noise distribution to be added and the characteristic parameters of the noise. Here are examples of Gaussian noise and salt and pepper noise. Among them, the characteristic parameters of Gaussian noise are the mean and variance, and the characteristic parameters of salt and pepper noise are the percentage of the noise-contaminated area in the entire image. These characteristic parameters are all set by manual input in the pop-up window, which is similar to that shown in the image rotation. When denoising, it is realized by filtering the noise that has been added. The function filter is used in MATLAB. Its input parameters are similar to the `imnoise` function. The denoising filter templates listed here include low-pass filtering, median filtering, and mean filtering. Salt and pepper noise function `f1=imnoise(f,'salt & pepper',x1);` Gaussian noise function `f1=imnoise(f,'gaussian',x1,x2);`.

2.7. Contrast enhancement

The method of image gray value transformation is adopted, that is, the gray value of the image pixel is changed to change the dynamic range of the image gray and enhance the contrast of the image. Suppose the original image is $f(m,n)$, and the processed image is $g(m,n)$, then the contrast enhancement can be expressed as follows.

$$g(m,n) = T[f(m,n)]$$  \hspace{1cm} (5)

Among them, $T[·]$ represents the gray-scale transformation relationship (function) between the enhanced image and the original image.

The brightness stretching transformation relationship is as follows. $k$ is called the slope of the transformation function (straight line).

$$g(m,n) = c + k[f(m,n) - a]$$  \hspace{1cm} (6)

$$k = \frac{d - c}{b - a}$$  \hspace{1cm} (7)

Logarithmic transformation is one of the commonly used gray-scale nonlinear transformation methods, and its general expression is as follows.

$$g(m,n) = \lambda \log(1 + f(m,n))$$  \hspace{1cm} (8)

Among them, $\lambda$ is an adjustment constant, which is used to adjust the gray value after transformation to make it meet the actual requirements. The function of logarithmic transformation is to expand the low-gray range of the image and compress the high-gray range at the same time, so that the gray distribution of the image is uniform and matches the human visual characteristics.

2.8. Histogram equalization and image smoothing

Histogram equalization refers to the gray scale nonlinear transformation of the image, so that the
The probability density distribution of the gray scale becomes constant, that is, the histogram becomes a uniform distribution. The basic idea of histogram equalization is to change the histogram of the original image into a uniform distribution, expand the dynamic range of the pixel gray value, and enhance the overall contrast and clarity of the image.

Image smoothing can use ideal low-pass filter or Butterworth low-pass filter. The transfer function of the ideal low-pass filter is as follows.

\[ H(u, v) = \begin{cases} 1 ; D(u, v) \leq D_0 \\ 0 ; D(u, v) > D_0 \end{cases} \]  

The pop-up window setting parameter function is also used here. The default cut-off frequency radius is 300, and the value of this experiment is 50.

The transfer function of the Butterworth low-pass filter is as follows.

\[ H(u, v) = \frac{1}{1 + (\sqrt{2} - 1)(\frac{D(u, v)}{D_0})^{2n}} \]  

The function of pop-up window setting parameters is also used here. The default cut-off frequency radius is 300 and the default order is 1. However, the cut-off frequency radius of this experiment is set to 50, and the order is still 1. Compared with the previous result, it is obvious that the effect is better.

**Figure 4** The corresponding characteristic curve of ideal low-pass filter.

**Figure 5** The corresponding characteristic curve of Butterworth low-pass filter.

### 2.9. Laplacian sharpening

The reason for the blurred image is that the imaging system is not focused well or the channel is too narrow, the contour of the target object is blurred after averaging or integration, and the details and contours (edges) are not clear. The purpose of image sharpening is to emphasize the outline of the target and make the blurred image clear. The methods are classified by Spatial differential division method and Frequency domain high-frequency boost filter method. Here we discuss the airspace sharpening method. Differentiation, as a method of finding the rate of change in mathematics, can be used to solve the changes in the abrupt parts of the image such as the contours and details of the target. Laplace sharpening method is one of the commonly used methods, and the formula is as follows.

\[ g(x, y) = f(x, y) + \alpha \left[ -\nabla^2 f(x, y) \right] \]  

\[ g(m,n) = f(m,n) + \alpha \nabla^2 f(m,n) = f(m,n) + \alpha \left[ \nabla^2 f_m + f_n \right] \]  

\[ = f(m,n) - \alpha f(m+1,n) + f(m-1,n) + f(m,n+1) + f(m,n-1) - 4f(m,n) \]  

\[ = (1+4\alpha)f(m,n) - \alpha f(m+1,n) + f(m-1,n) + f(m,n+1) + f(m,n-1) \]  

There are generally two types of Laplacian sharpening templates: 4-neighbor template \((W1)\) and 8-neighbor template \((W4)\). The source code and experimental results are as follows.

\[ W_1 = \begin{bmatrix} 0 & -\alpha & 0 \\ -\alpha & 1 + 4\alpha & -\alpha \\ 0 & -\alpha & 0 \end{bmatrix} \]  

\[ W_4 = \begin{bmatrix} -\alpha & -\alpha & -\alpha \\ -\alpha & 1 + 8\alpha & -\alpha \\ -\alpha & -\alpha & -\alpha \end{bmatrix} \]
2.10. Edge detection, image segmentation
The discontinuity of the gray value of the gray image can be used for edge detection. For the edge of the image, the expression in mathematics is: the maximum and minimum of the first derivative, the zero crossing of the second derivative, but in actual application, due to the large amount of calculation of the derivative, some simple operators are usually used to replace the calculation of the derivative. According to the different simple operators, the edge detection of grayscale images can be realized by different operators in MATLAB. In the MATLAB image processing toolbox, the edge function is commonly used to perform edge detection on grayscale images, and there are six edge detection operators in the edge function: Sobel, Prewitt, Roberts, LoG, ZeroCross and Canny, different edges The detection operator has different detection effects.

We often use otsu for image segmentation. OTSU is a global binary algorithm, which divides the image into two parts, the foreground and the background, according to the gray-scale characteristics of the image[6]. When the optimal threshold is obtained, the difference between the two parts should be the largest. The standard to measure the difference used in the OTSU algorithm is the more common maximum between-class variance. If the inter-class variance between the foreground and the background is larger, it means that the difference between the two parts that make up the image is greater. When part of the target is mistakenly divided into the background or part of the background is mistakenly divided into the target, it will cause the difference between the two parts. Decrease, when the threshold segmentation makes the variance between classes the largest, it means that the probability of misclassification is the smallest.

2.11. Image stylization
Process the image, make it stylized, and make it show different styles, we can make it show reflection, relief, and sketch style. We used random offset for reflection processing, and Gaussian blur and overlay for sketch processing.

3. Results and discussion
The functional design results are as follows.

Figure 6 Grayscale  Figure 7 Rotated image

Figure 8 Horizontally flipped image  Figure 9 Vertically flipped image
Figure 10 Image processed by DFT
Figure 11 Image processed by DCT
Figure 12 Image after adding noise
Figure 13 Image after denoising
Figure 14 Image after sharpening
Figure 15 Image after edge detection
Figure 16 Image after OTSU
Figure 17 Anaglyph effect
Through observation, figure 6-18 shows the functions of our image processing toolbox. It can be seen that based on MATLAB GUI, we have realized different types of image processing with good results. However, the effect of image stylization function does not reach the expectation, so the accuracy and satisfaction of processing can be improved by changing the parameters.

4. Conclusion
We designed an image processing toolkit based on MATLAB GUI to realize image reading, storage, display, noise addition, denoising, enhancement, edge detection, image segmentation, discrete Fourier transform, wavelet transform, feature extraction, Target recognition, color image processing and other basic functions, while adding novel functions of image stylization, to achieve sketch, relief, reflection and other filter functions[7]. The function rendering effect is still good, but there is still room for improvement. In the later stage, the algorithm can be improved to improve the satisfaction of image processing.

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