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Research on Feature Enhancement and Rendering of Weak Invisible Video Anti Counterfeiting Images

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Abstract: The information in weak invisibility images is often difficult to detect, and enhancing them has practical value. This article mainly adopts a weak invisible image hidden information extraction algorithm based on color channel feature extraction and multi threshold segmentation fusion comparison, as well as an enhanced rendering algorithm based on anti-counterfeiting information. It has a practical mechanism in extracting anti-counterfeiting information, enhancing visibility, improving visual quality of images, and detecting anti-counterfeiting images.

Keywords: weakly invisible anti-counterfeiting images; image information enhancement; FFmpeg; information visibility; printing quantum dots

I. INTRODUCTION

In today's digital age, image security and information hiding have become hot topics in technological development, especially in application scenarios such as anti-counterfeiting technology and digital watermarking. With the continuous development of this field, the processing of weak invisible images has gradually attracted attention. Weak invisible images refer to images that carry information that is difficult to detect, and their application scope covers multiple fields from identity authentication to anti-counterfeiting traceability. However, due to the weakness and concealment of information, the processing and enhancement of weak invisible images are still continuously developing. In existing research, many weak invisibility image processing methods have emerged, such as utilizing frequency domain transformations, optical principles, visual cryptography, etc. However, there are still some limitations in terms of visibility, accuracy, and real-time performance. Traditional methods may lose some details when extracting information, while some emerging technologies may be limited by real-time performance. Therefore, it is necessary to seek new perspectives and methods to improve the effectiveness of weak invisibility image processing. The research background of this article is based on the understanding of weak invisibility image processing problems and the limitations of existing methods. A hidden information extraction algorithm is adopted for weak invisibility video anti-counterfeiting images, aiming to enhance image information and improve its visibility.

II. ALGORITHM DESIGN

The algorithm designed in this paper for the enhancement and rendering of features in weak invisible video anti-counterfeiting images consists of four key steps, outlined as follows:

Step 1: Extract frames from the video to obtain a set of images for processing, laying the foundation for subsequent steps and ensuring the comprehensive utilization of information throughout the entire process.

Step 2: Conduct color channel feature extraction and multi-threshold segmentation on the frames of the video to extract anti-counterfeiting information hidden in weak invisible images, providing a baseline for the subsequent enhancement process.

Step 3: Enhance and render the extracted anti-counterfeiting information from weak invisible images, obtaining an effect image with improved visibility, presenting a clearer and more accurate overall image.

Step 4: Overlay the enhanced effect image with the original image, synchronously compose the generated image set into the video, creating a completely new video. This effectively integrates the enhanced image into the original video, producing a final output with enhanced anti-counterfeiting effects.

2.1 Video Frame Extraction and Composition

2.1.1 Frame Extraction

To shift the video processing into the realm of image processing, frame extraction is necessary to meet the requirements of image feature extraction and manipulation. FFmpeg is a powerful open-source video processing tool widely utilized across various applications. It encompasses audio and video encoding/decoding functionalities, facilitating conversion between different codecs, allowing users to choose between various formats and qualities. Additionally, FFmpeg boasts capabilities in streaming media processing, supporting tasks such as streaming, transcoding, and adhering to protocols like RTMP and HLS.Moreover, FFmpeg includes features such as video capture, screenshotting, and adding watermarks to videos, providing a multifaceted approach to video processing [2]. Therefore, this study employs the FFmpeg tool for the extraction of video frames and subsequent operations based on those frames. The key settings for the two video frame extraction methods are outlined in Table 1.

Table 1: Key Settings for Video Frame Extraction

	Using tools	input video	output format	frames per second	video quantizer	output image
Method 1	FFmpeg	-i input.mp4	—	-r frame rate	—	image%d.jpeg
Method 2	FFmpeg	-i input.mp4	-f image2	-vf fps=frame rate	-qscale:v 2	image%d.jpeg

Comparing the two frame extraction methods, the following conclusions can be drawn: Method 1 extracts frames by simply specifying the frame rate without explicitly defining the output format and image quality. In general, Method 1 is more straightforward, requiring lower image quality, and is suitable for scenarios where rapid extraction is essential. On the other hand, Method 2, by allowing control over the output image format and quality and utilizing the 'fps' filter in the video filter '-vf,' offers greater flexibility. This allows users to adjust parameters according to specific requirements, making it more adaptable to real-world application scenarios.

2.1.2 Compound

With the powerful processing capabilities of the FFmpeg tool, achieving composite processing of the video is made possible. This process involves synchronously overlaying the effect image enhanced and rendered with the original video sequence. Not only does this retain the fundamental information of the original video, but it also generates an entirely new video through visual improvements. This processing enriches the visual presentation of the original video, providing a different visual experience and enhancing the overall visual appeal. The specific steps for video composition are as follows:

Step 1: Set up the tools and cache path, using FFmpeg.
Step 2: Set the input image frame rate, specifying the frame rate with '-r.'
Step 3: Set the starting number for the input image sequence to ensure correct recognition of the image order by FFmpeg, using '-start_number.'
Step 4: Specify the input image sequence format using '-i,' such as '-i image%d.jpeg.'
Step 5: Set the output video frame rate with '-vf fps=frame_rate.'
Step 6: Specify the output file as 'new.mp4.

2.2 Information Extraction of Weakly Invisible Anti-Counterfeiting Images

The weak invisible anti-counterfeiting image extracted from the video using the FFmpeg tool is processed to remove the background quantum dot portion without embedded anti-counterfeiting information, retaining the hidden dot matrix information and revealing the information in the weak invisible anti-counterfeiting image. This step includes:

2.2.1 Utilizing Color Channel Operations

The weak invisible anti-counterfeiting image proposed in this study is a blue channel printed quantum dot image. The generation principle of this image involves embedding the required anti-counterfeiting information into the B channel of the RGB image. During this process, the invariance of the pixel values of the R and G channels is preserved, ensuring consistency in the overall visual effect between the generated image with embedded information and the original image.

Based on the embedding principle, color channel operations are used for feature extraction. Firstly, information from the R, G, and B channels is extracted and temporarily stored from the anti-counterfeiting image. Subsequently, multiple subtraction operations are performed between the two channels, resulting in various output images. In the original anti-counterfeiting image, the R and G channels do not contain anti-counterfeiting information, so in the output images, the pixel values of these two channels change minimally, presenting a darker background. The pixel values of the anti-counterfeiting information points in the B channel are 0. In the resulting images from the operations, the pixel values of points with anti-counterfeiting information remain unchanged, appearing as white dots, while the background pixel values decrease.

However, during the color channel operations, there may be cases where the R or G component is too small. After subtraction, the difference between the pixel values of points with anti-counterfeiting information and the background values may be close, potentially leading to an inaccurate extraction of anti-counterfeiting quantum dots. To address this issue, a method of merging and comparing multiple result images is adopted to reduce the adverse consequences of incomplete extraction due to excessively low R or G components.

2.2.2 Multiple Threshold Segmentation Technique

Based on the pixel values of different result images, corresponding thresholds are generated, and the average pixel value can also be used as the threshold. The formula is as shown in equation (1):

$$\mathrm{T(result)} = \frac{1}{\text{total pixels}} \sum_{\text{pixel} \in \text{result}} \text{pixel} \quad (1)$$

Binary image sets are generated according to these thresholds, effectively segmenting the anti-counterfeiting information points from the background. The anti-counterfeiting quantum dots are set to 1, while the remaining areas are set to 0.The formula is as shown in equation (2):

$$F_{BI}(result, T(result)) = \begin{cases} 1, & result > T(result) \\ 0, & otherwise \end{cases} \quad (2)$$

Due to the constant area size of the anti-counterfeiting information quantum dots, which is either 4×4 or 2×2 pixels, the binary images are processed by preserving quantum dots with matching areas and eliminating larger pixel blocks. This results in a filtered binary image.

The filtered binary images are then merged and added together to maximize the extraction of anti-counterfeiting quantum dot information. Through the information extraction algorithm for weak invisible anti-counterfeiting images, the extraction of anti-counterfeiting information is ensured to serve as a reference point in subsequent steps, facilitating information enhancement.

2.3 Image Information Enhancement and Rendering

Design and implement the enhancement and rendering of anti-counterfeiting information in the image to improve the visibility of weak invisible anti-counterfeiting images. This process includes using the extracted information as a foundation, designing rendering algorithms, and implementing enhancement effects such as color adjustment and edge halo enhancement. This enhances the anti-counterfeiting information in the image, improving the overall visual effect.

2.3.1 Anti-Counterfeiting Quantum Dot Information Edge Halo Enhancement

Firstly, perform edge extraction on the filtered binary image using the Sobel edge detection algorithm. The mathematical expression can be found in equations (3) - (6). Subsequently, create a Gaussian filter kernel and apply Gaussian filtering to the edge image to achieve a gradual gradient effect from far to near, attenuating the abruptness of the edge and enhancing the aesthetic appeal of the rendering effect. Finally, use the edge image as a template to enhance the contrast of the edge, aiming to make the brightness of the edge higher than that of the anti-counterfeiting quantum dots, thereby achieving enhanced display of the anti-counterfeiting information and obtaining the edge halo image.

$$G_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}, G_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \quad (3)$$

$$I_x(x,y) = \sum_{i=-1}^{1} \sum_{j=-1}^{1} G_x(x,y) \cdot B(x+i, y+j) \quad (4)$$

$$I_y(x,y) = \sum_{i=-1}^{1} \sum_{j=-1}^{1} G_y(x,y) \cdot B(x+i, y+j) \quad (5)$$

$$\mathrm{I_{magnitude}}\ (\mathrm{x,y}) = \sqrt{\mathrm{I_x(x,y)^2 + I_y(x,y)^2}} \quad (6)$$

Among them, B is the binarized image, B (x, y) is the value of pixel (x, y), G_x is the Sobel operator in the horizontal direction, G_y is the Sobel operator in the vertical direction, and B is convolved using G_x and G_y. I_x is the gradient image in the horizontal direction, I_y is the gradient image in the vertical direction, and $I_{magnitu\ de}$ is the edge intensity of each pixel.

2.3.2 Color Adjustment

To enhance the aesthetic appeal of the edge brightness, adjust the color of the edge halo by creating a 24-bit depth image. Any two of the R, G, or B values in the edge halo image can be set to 0 to adjust the color of the halo. Lastly, apply the edge halo effect image to the original image, generating an enhanced rendering effect image for the anti-counterfeiting information. Integrate these effect images to create a new video with significantly improved recognizability and visibility.

III. EXPERIMENTAL RESULTS AND ANALYSIS

3.1 Authentication of Anti-Counterfeiting Information Extraction

Select weak invisible anti-counterfeiting images with different color distribution characteristics as input images. Utilizing the aforementioned anti-counterfeiting information extraction algorithm, verify the extraction of anti-counterfeiting quantum dot information. Organize the extracted images obtained from the original embedded images' anti-counterfeiting information matrix, calculate the anti-counterfeiting information extraction rate for each image, and present the specific data in Figure 1.

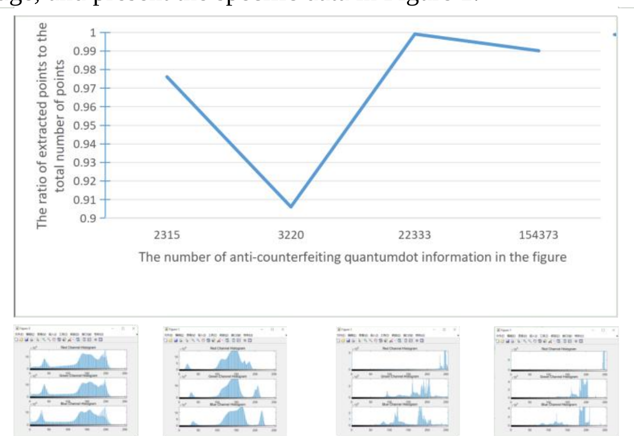

Figure 1: Data Chart for Extracting Anti Counterfeiting Information from Weak Invisible Anti Counterfeiting Images with Different Characteristics

As per the data in the figure, the anti-counterfeiting information extraction algorithm used in this study yields favorable results for weak invisible anti-counterfeiting images. The accuracy of information extraction is high, contributing significantly to the subsequent enhancement and rendering processes. The algorithm exhibits good robustness across weak invisible images with different characteristics, making it versatile in application. However, it is susceptible to the clarity of captured images, achieving an extraction rate of over 98% for high-resolution images.

3.2 Enhanced Information Rendering Comparison Chart

As per the data in the figure, the anti-counterfeiting information extraction algorithm used in this study yields favorable results for weak invisible anti-counterfeiting images. The accuracy of information extraction is high, contributing significantly to the subsequent enhancement and rendering processes. The algorithm exhibits good robustness across weak invisible images with different characteristics, making it versatile in application. However, it is susceptible to the clarity of captured images, achieving an extraction rate of over 98% for high-resolution images.

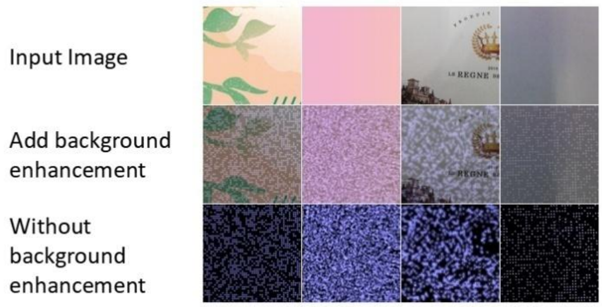

Figure 2 Comparison chart of anti-counterfeiting information enhancement effect

Selecting specific frames from the video as the colored original images for the enhancement and rendering algorithm, an analysis and comparison were conducted with the video frames after overlaying the enhanced anti-counterfeiting information rendering effects, as illustrated in Figure 2. Two types of enhanced images can be generated, namely, those preserving the background and those without. Background-preserving enhancement retains the background content of the original colored image while enhancing the display of anti-counterfeiting information. This approach, by preserving the original image content, better emphasizes the anti-counterfeiting information. Background-removed enhancement, on the other hand, eliminates the original background, retaining only the extracted anti-counterfeiting information. This method focuses on showcasing the anti-counterfeiting information itself, making the extracted information clearer and more prominent by removing background interference. Based on the comparative results in Figure 2, not only can the visibility and reliability of the rendering algorithm be intuitively demonstrated, but it also provides a detailed understanding of the information enhancement effect. The contrast between the enhanced rendering results and the original image is notably evident, resulting in a visually impactful presentation.

IV. EXISTING PROBLEMS AND SOLUTIONS

Regarding the concealment of anti-counterfeiting information in weak invisible anti-counterfeiting images, there are already numerous mature and practical technologies, such as halftone image information hiding, digital watermarking, optical information hiding, steganography, and designing models using deep learning to embed anti-counterfeiting information. However, there are still some challenges to explore in effectively revealing this information and enhancing the visual perceptual effects of the images.

Current technologies face a trade-off between accuracy and efficiency during the information extraction process. Future developments could focus on balancing accuracy while minimizing recognition time and increasing efficiency. Establishing methods for advantageous evaluations of visual perceptual effects is another avenue for exploration. Introducing psychological and human-computer interaction assessments could gauge user engagement during the information presentation process. This comprehensive approach aims to measure and evaluate visual perceptual effects, helping design image enhancement methods that align better with user expectations and needs. The information embedded in weak invisible anti-counterfeiting images may involve multiple modalities, including images, text, sound, etc. Effectively integrating these multimodal information sources, ensuring coherence and accuracy in the integrated information, highlighting the advantages of different modalities, and ultimately establishing and refining effective connections between multimodal information are crucial. Ensuring consistency among different modalities through in-depth research on multimodal information integration can make weak invisible anti-counterfeiting image processing more comprehensive and diverse. This could provide users with a richer, more expressive, and comprehensive multimodal visual experience.

V. CONCLUSION

Due to the imperceptibility of anti-counterfeiting information in weak invisible anti-counterfeiting images, and the challenges of blurred recognition and the lack of engagement and experiential sensation during the recognition process, a key issue in the field of enhancing weak invisible anti-counterfeiting images is addressed. A feature-enhanced rendering algorithm for weak invisible anti-counterfeiting videos is designed. This algorithm takes anti-counterfeiting image information as a baseline and employs information enhancement as a method. The algorithm involves color channel feature extraction, multiple threshold segmentation operations on video frame images, and the utilization of perceptual differences in color, brightness, and enhancement as perceived by the human eye. Experimental results demonstrate that the feature-enhanced rendering algorithm for weak invisible anti-counterfeiting videos achieves a high extraction rate for characteristic points in anti-counterfeiting images with different features. It provides broader applicability for the processing of various anti-counterfeiting images. The generated image enhancement effects are significant, presenting a visually appealing result that markedly improves the visibility and concealment of weak invisible anti-counterfeiting images with hidden information. However, further exploration and optimization are required, especially in scenarios with high real-time requirements.

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