GAN Image Generation and Detection Technology Based on Fractal Dimension

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Abstract. With the development of modern technology today, image analysis technology has become an important research direction in the computer field. Computer image processing technology is a cross and fusion involving multiple disciplines, which includes multiple research directions such as physics, chemistry, and computer science. Starting from the fractal dimension, this article studies the image generation and detection technology. The purpose of the research topic in this article is to have a deep understanding of image generation technology so as to master image processing methods proficiently. The methods used in this article include case analysis, data, comparison, and experimental methods, etc., and carry out related researches on image generation detection technology and fractal dimension. The experimental results show that the algorithm accuracy of GAN in the detection technology of computer-generated images is higher than other algorithms, and the improvement space is about 0.06.

1. Introduction

Modern machine vision systems based on fractal dimensions have been widely used in many fields. The fractal dimension of an image is a very important and generally valued technology. It has a lot to do with our requirements for information processing speed, data storage capacity, and image resolution under different objects and environments in practical applications. Therefore, people have been committed to studying how to efficiently use existing equipment to achieve high-quality, high-precision conversion of two-dimensional images into digital images and generate fractal dimensions that can be used in engineering practice.

There are many researches on image generation and detection technology. For example, Liu Jun proposed a composite edge detection algorithm based on multifractal theory and mathematical morphology in response to the problem of license plate image positioning and processing in the existing license plate recognition technology [1]. Zhou Linna said that the introduction of generative confrontation networks into steganography can reduce the traces of carrier modification and improve the concealment of steganography [2]. Wang Wang said that image super-resolution is a technology that uses software algorithms to improve image spatial resolution [3]. In order to improve the stability of GAN, Zhang Guanghua proposed an improved neuron abandonment method [4]. Therefore, the research of GAN's image generation and detection technology in this paper is closely following the pace of scholars and has the significance of the times.

This dissertation first studies the related knowledge of fractal and fractal dimension, and secondly studies the image desiccation and image super-resolution reconstruction. Then the research is on the edge detection technology of digital image, and the algorithm research is carried out. Finally,
analyzing and experimenting around computer-generated images and detection, and get the final result.

2. GAN Image Generation And Detection Technology Based on Fractal Dimension

2.1. Fractal Dimension
(1) Fractal Features
Fractal sets all have proportional details at arbitrarily small scales. The fractal set has a self-similar form. The method of defining fractal sets is very simple [5-6].

(2) Fractal dimension
Dimension is the number of coordinates of a point in a geometric object. The fractal dimension reflects the efficiency of the space occupied by complex shapes. The formula can be expressed as:

$$c = \lim_{\delta \to 0} \left[ \frac{\log M(\delta)}{\log(\frac{1}{\delta})} \right]$$

(1)

Where \( \delta \) is the length of one side of the small cube, \( M(\delta) \) is the number obtained.

Generally speaking, when calculating the fractal dimension of an image, the calculation method must first be selected according to a specific fractal pattern. The image fractal model is compatible with different image fractal dimension calculation methods [7-8].

(3) "Box" dimension

The set X in s dimension, if X can be expressed as a subset \( S_a \) that does not cover each other, then X is self-similar. The fractal dimension F is as follows:

$$F = \frac{\log(S_a)}{\log(1/a)}$$

(2)

Among them, a is the scale factor and the number of subsets.

Assuming that the highest and lowest gray values in the (m,n)th grid respectively fall in the Ith and hth small boxes, then the distribution of \( S_a \) in the (m,n)th grid is:

$$S_a(m, n) = I - h + 1$$

(3)

(4) Application of fractal dimension in image field

1) Fractal coding
Fractal image coding is to divide the graph into w blocks, and then search for p blocks that match it in the image, and perform affine transformations such as spatial shrinkage, rotation, reflection, and brightness transformation on the p blocks [9-10].

2) Image segmentation
In image processing, in order to describe and analyze an image, it is often necessary to subdivide the image into several sensitive areas. This technique of dividing an image into multiple hot spots for effective post-processing is called image segmentation.

3) Image texture analysis
Fractal dimension is the main measurement tool used in other fractal image processing techniques. As a measure of the unevenness of the image surface, the fractal dimension can not only measure the complexity, but also show the invariance of multi-scale and multi-resolution changes [11-12].

2.2. Image Denoising Method Based on Generative Adversarial Network
(1) GAN network
Generative adversarial network is an unsupervised learning method, which is widely used in various fields of computer vision. The original generative confrontation network is used to learn the sample images in the image library, so as to generate images similar to the samples in the library. The advantage of generating an adversarial network is that it does not memorize image sample blocks through the network and piece the sample image blocks together into output images, but learns the
image characteristics of the sample image blocks in the database and uses the features to reconstruct the image. In order to avoid the loss of more image details when denoising the image, the multi-scale features containing redundant information are extracted for subsequent denoising. In addition, other channel features still retain the structural information, and images with clear texture details can still be restored during image fusion. The convolutional network with weight sharing is used in the generation network, because the shared weight structure is closer to the biological visual system, which reduces the complexity and parameter amount of the network, and has stronger adaptability and robustness [13-14]. The specific block diagram is shown in Figure 1:

![Figure 1. Generate the overall structure of the network](image)

(2) Feature extraction
Using multi-scale convolution kernel to process the image, you can extract the information of different scales of the image, and convert the image into a feature domain. Processing images in the feature domain can not only retain more image information, but also has more room for optimization when the generating network and the discriminant network are used for confrontation training.

(3) Domain denoising
Since the image input to the generation network is a noisy image, the multi-scale features output by the feature extraction layer are also features contaminated by noise. For these noisy features, this paper uses a stacked convolutional layer structure to extract the noise in the feature, and through cross-layer connection, the noisy feature is subtracted from the extracted noise to obtain the denoised image feature for subsequent use Network processing.

(4) High-level feature extraction
After obtaining the denoising results of the feature domain, it is necessary to perform multi-dimensional fusion of the input denoising features, and use the abstraction of high-dimensional features and the information retention ability of low-dimensional features to strengthen the network's fitting ability.

(5) Dimensionality reduction fusion
The multi-layer network is used to filter the features in the image, and the features that contain noise or loss of information are removed from the feature domain. And gradually merge the features suitable for the restored image, and use the non-linearity of the multi-layer network to construct the correct denoising image.

2.3. Image Super-resolution Reconstruction of Generative Adversarial Network
With the increase in the number of layers of convolutional neural networks, the image quality of super-resolution reconstruction is also improving. Generative confrontation networks have achieved great success in the field of computer vision. The image super-resolution method based on generative confrontation network is a network model that is more in line with subjective visual effects.

The generation of the confrontation network does not require repeated sampling of the Markov chain. It is mainly to learn the probability distribution of the real data through the training data of the sample, so that the generated sample distributes the data in the same way as the actual data. In the training process of generating the adversary network, first repair the generator, train the discriminator to distinguish between real data and fake data, and then repair the discriminator, train the generator to
generate deceptive data current discriminator, repeat the above process, optimize the creation of the grid and distinguish grid. The loss function can be expressed as follows:

\[
\min \max_W \mathbb{E}_{G} \left[ \mathbb{E}_{s_{\text{data}}} (a) \left[ \log G(a) \right] + \mathbb{E}_{s_{\text{neutral}}} (c) \left[ \log(1 - G(F(c))) \right] \right]
\]

(4)

Generating the loss function of the adversarial network is a minimum-maximum optimization process, which is essentially two optimization problems.

The discriminant network takes the super-resolution image and the original high-resolution image as input, and outputs the discrimination result. The generative network and the discriminant network confront each other. When the discriminant grating cannot be distinguished strongly, SRGAN has completed the task of reconstructing super-resolution images. The super-resolution image reconstructed by the SRGAN model will appear blurry at higher magnifications, and the generation of the adversarial network itself is also unstable.

2.4. Digital Image Edge Detection Technology

Edge detection is the process of identifying sudden changes in brightness and discontinuous points in the image through edge detection operators and positioning the edges according to the positions of these points. Search-based edge detection uses the first derivative of the gray curve to obtain the brightness gradient of the original data to find the peak value in the image brightness gradient. The geometric shape of the peak point is the edge. Based on the zero-crossing method, the derivative is obtained from the image to determine the edge.

Image acquisition is the first prerequisite for edge detection and subsequent analysis. Discretize the collected images, and convert continuous gray values into discrete values through quantization. The collected images are preprocessed before processing and analysis to remove redundant information and reduce the amount of calculation.

2.5. Algorithm Research

Since the communication signal has certain modulation characteristics, its fractal dimension and noise have different randomness, so this difference can be used to construct a spectrum sensing model. Among them, the randomness of the communication signal mainly depends on the modulation type and the phase of the carrier, and noise has little effect on its randomness, that is, within a certain range of signal-to-noise ratio, the fractal dimension is not sensitive to noise.

(1) Katz fractal dimension

The method of calculating the fractal dimension according to Katz is derived from the fractal dimension of the plane curve. The fractal dimension of the curve can be expressed as:

\[
H = \frac{\lg(G)}{\lg(\delta)}
\]

(5)

The total length and distance of the curve are accumulated to get:

\[
S = \sum_{i=1}^{M-1} \left( g_{i+1} - g_i \right)^2 + \left( h_{i+1} - h_i \right)^2
\]

(6)

(2) Sevcik fractal dimension

Suppose the signal waveform length is L, which is composed of a series of points. First, normalize the signal waveform:

\[
A_i^* = \begin{cases} A_i & A_{\max}, \ B_i^* = \begin{cases} B_i - B_{\min} & B_{\max} - B_{\min} \end{cases} \end{cases}
\]

(7)

2.6. Computer-generated images and their detection

Computer-generated images are mainly generated by 3D software such as 3D Max and Maya, which are mainly based on the principles of computer graphics.

(1) Blanking technology
The use of computers to generate realistic images of three-dimensional objects is an important part of computer graphics research. Projective transformation usually causes blurred images. In order to resolve the ambiguity, invisible lines or areas need to be eliminated. In line blanking, the most basic operation is to determine the occlusion relationship with the line. The body must also be decomposed into curved surfaces, and then the occlusion relationship between the curved surfaces and the lines must be evaluated. When evaluating the occlusion, the cutting operation between the lines needs to be repeated.

(2) Eliminate hidden surfaces
Ray tracing technology. The most basic ray tracing algorithm is to follow specular reflection and refraction.

(3) Texture mapping technology
During the mapping process, the texture is converted to the surface of the 3D object to create the final image.

(4) Shadow generation technology.
The shaded area is a semi-open three-dimensional area, with the illuminated area as the top area. Each object area contained in the shadow box must be a shadow box. The field of view The screen field usually represents a square pyramid. Use this square cone to crop the shadow field of the object.

3. Computer-Generated Image Detection Algorithm Experiment

3.1. Experimental Environment
The experiment uses the Python interface of the deep learning framework to build the SRWGAN algorithm model.
Processor: Intel, Core, CPU
Memory: 64GB
Graphics card: NVIDIA
The experiment uses the SRGAN model as a benchmark, and uses subjective visual evaluation and objective quantitative data as evaluation indicators. Three experiments are set up: First, the comparison between different interpolation algorithms and the experimental analysis of the improvement of the residual structure. Second, the comparison between loss functions. Third, the experimental analysis of the entire improved model.

3.2. Experimental Comparison of Improved Generative Model
Mainly introduce the experiment and result analysis of the SRWGAN generative model. The parameters of each layer of the improved generative network are shown in Table 1. Name the convolutional layers 1, 2, 3, 4, and 5 from left to right.

| Layer | Convolution kernel size | Convolution kernel number | Step size |
|-------|-------------------------|---------------------------|-----------|
| 1     | 4*4                     | 32                        | 1         |
| 2     | 4*4                     | 32                        | 1         |
| 3     | 9*9                     | 4                         | 1         |
| 4     | 4*4                     | 32                        | 1         |
| 5     | 4*4                     | 128                       | 1         |

4. Analysis of Experimental Results
The algorithms used in this article include generative adversarial networks, recursive algorithms, residual networks and loss functions. The specific experimental results are shown in Table 2:
Table 2. Results of Different Super-Resolution Algorithms

| Algorithm | Average time | PSNR/SSIM | Promote |
|-----------|--------------|-----------|---------|
| SRGAN     | 0.187        | 31.56/0.845 | +0.08/+0.007 |
| VDSR      | 0.157        | 31.65/0.875 | +0.07/+0.005 |
| SRWGAN    | 0.165        | 31.54/0.869 | +0.05/+0.003 |
| DRCN      | 0.135        | 31.95/0.898 | +0.02/+0.001 |

Figure 2. Results of Different Super-Resolution Algorithms

As shown in Figure 2, we can see that among the four algorithms, the RSNP value recursive algorithm has the highest data, while the SSIM data has the highest residual network. The one with the most value increase uses the generative adversarial network algorithm. This shows that the accuracy of the generative adversarial network algorithm in discrimination is higher.

5. Conclusion
Fractal dimension is an important method in solid geometry. It has extensive and in-depth applications in solving complex problems and optimizing design. It can not only provide important information as digital signal processing, radar system and remote sensing technology. It also has many functions that are not involved in other disciplines or have not yet been developed. GAN is an optical network analysis system based on fractal dimension. This technology is mainly used to detect changes in the shape and size of objects. The principle of GAN scanning is to analyze the pixel positions and topographic features of each point in the image in different regions, so as to obtain the image classification. The research results of this paper show that the role of generative adversarial networks in image generation is relatively large, and its accuracy is relatively high and it is worth a try.

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