

An Interpolation Method to the Construction of Error Diffusion Filter

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Abstract

In this paper, we proposed a new error diffusion filter construction method for digital halftoning with random space-filling curve. A random space-filling curve is introduced to incorporate some randomness for regular space-filling curve such as Peano curve and Hilbert curve. Since the round error is propagated to adjacent pixels whose output values have not been determined, the error diffusion filter is not fixed. So, error diffusion filter is determined dynamically according to those adjacent pixels and uniform distribution method about adjacent pixels or single pixel distribution along scanning curve path. We used interpolation technique to these two distribution method to get better quality halftoning results. We showed the experimental results of proposed method.

Keywords: *Digital halftoning, Error diffusion, Space filling curves*

1. Introduction

Digital halftoning is a relatively well-known image processing techniques that converts a continuous tone grayscale digital image into a binary image consisting of black and white pixels. Error diffusion method is one of digital halftoning techniques that transform a continuous gray scale image into a black and white image pixel by pixel and get a good result by diffusing the resulting errors into neighboring pixels. In this paper, we deals with problems related to digital half-toning algorithm proposed by Asano which uses random space filling curve(RSFC)[1, 2]. His algorithm distributes the resulting error to neighboring pixels along the RSFC. With respect to these problems, improvement is proposed in [3] by along the scanning curve the error diffusion only to the next pixel. In this paper, we address the problem of excessive bright pixel segments that occur in the resulting halftone image and the cause of this artifact. And we also proposed one pixel only error diffusion method as an improvement.

2. Previous Works

Space-filling curves, was discovered by Giuseppe Peano in 1890, these curves can cover the entire unit square in two dimensions. These curves have Peano curves, Hilbert curve, Sierpinski curve, and provides a method that can to visit in turn on all points in space. It is possible for these properties to visit in turn on the pixels of the digital image with a finite size.

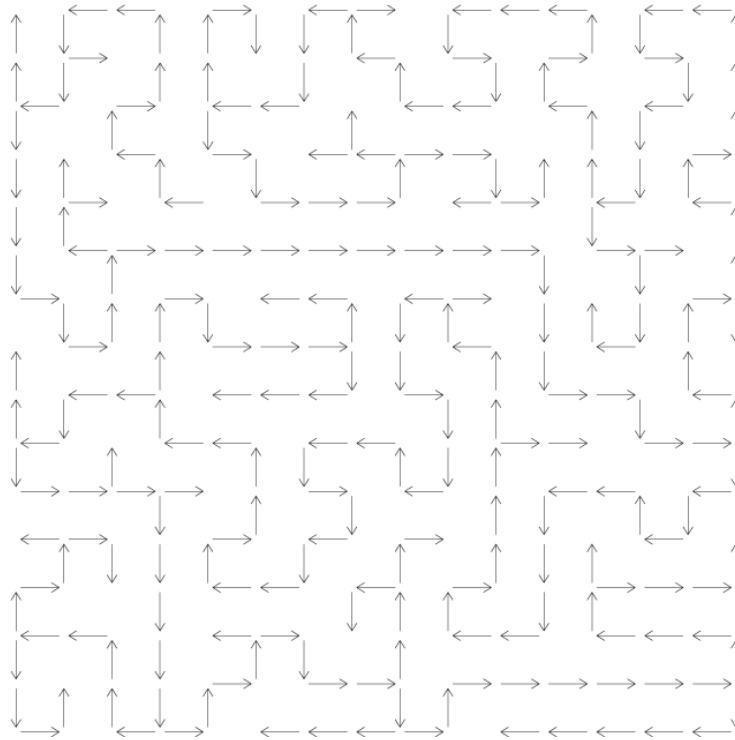


Figure 1. The example structure of random spanning tree

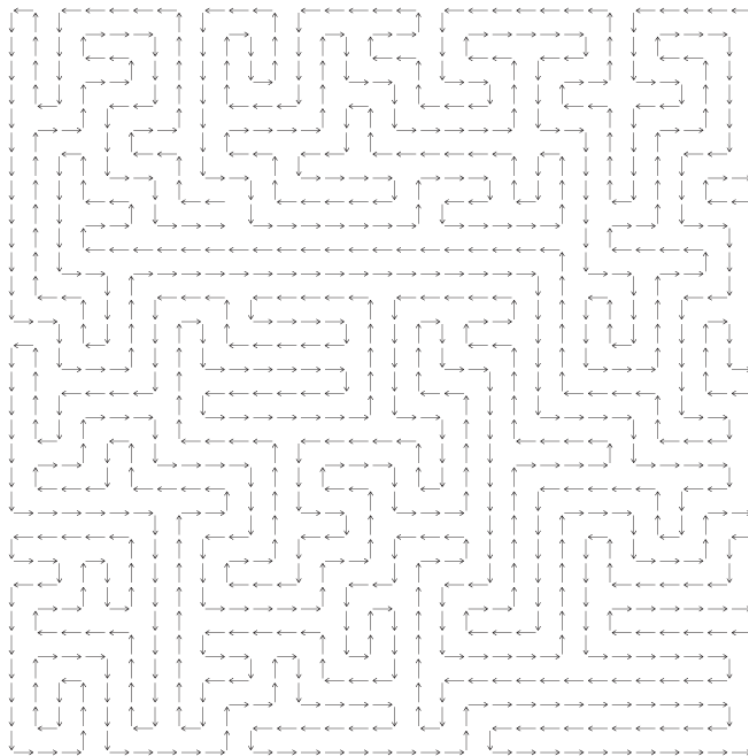


Figure 2. The example structure of random space filling curve

Due to their characteristics has self- similarity, they can reduce the pattern that may occur in the zigzag scan or raster scan. It has been used for the first time by Witten in [5] and used in a new way digital halftoning methods [6, 7]. However, void filling these curves, reduce the pattern of certain video processing order in which the direction of ever-changing, but they can generate a pattern in the form of another unique for self- similarity.

In addition, in order to reduce the repetitive patterns of SFC [1, 2] use a RSFC. In other to generate a RSFC like in Figure 2, we need to build a maze like random spanning tree first. And form a RSFC by tracing the wall of random spanning tree like in Fig. 1 along both sides. The drawback of digital halftoning using RSFC is an extremely bright pixel segment can be occurred in the resulting image, experimental results are represented in Figure 3 and Figure 5. In the case of [2] to solve this problem, only about 76% of the error is diffused. This can prevent too long error propagation but resulting image also can be darkened too. In [1] adaptive method which distributes larger portion of the error to neighboring pixels which receive error from smaller number of pixels is used. These methods reduce the artifact somewhat, but basically the problem is difficult to remove.

3. The Proposed Method

In this paper, we try to improve by interpolating the two ways of existing. One method may be a method of uniformly diffused on the neighboring pixels that have not yet been processed error, and described as follows.

$e(p_i \rightarrow p_j) = \frac{E(p_i)}{n(p_i)}$, where $n(p_i)$ is the number of pixels that have not been processed around the pixel p_i

Assuming that the current pixel is p_i and the target pixel is p_j , we get total diffused error $e(p_i \rightarrow p_j)$ to is $E(p_i)$ divided by $n(p_i)$, where $E(p_i)$ is accumulated error in p_i . On the other hand, in the case of the method along the processing path, the error diffusion the pixels corresponding to the following process, they are as follows.

$$e(p_i \rightarrow p_j) = \begin{cases} E(p_i), & \text{when } p_j \text{ is the next pixel of } p_i \text{ along scanning curve} \\ 0, & \text{otherwise} \end{cases}$$

By introducing a parameter α to interpolate both of these methods, the proposed method is calculated as follows.

$$e(p_i \rightarrow p_j) = \begin{cases} \alpha E(p_i) + (1 - \alpha) \frac{E(p_i)}{n(p_i)}, & \text{when } p_j \text{ is the next pixel of } p_i \text{ along scanning curve} \\ (1 - \alpha) \frac{E(p_i)}{n(p_i)}, & \text{otherwise} \end{cases}$$

When calculated as described above, it is possible in accordance with the α , to obtain different results, two methods existing, can be seen in the special case α is 0 or 1.

4. Experimental Results

In this paper, the experiments were performed while changing the value of α for the same random space-filling curve, by applying the error diffusion halftoning. Images were used for experiments shown for easy comparison to cut only the part with the Lena image which resolution is 256 by 256. In the case of $\alpha = 0$, it will get the same results as a method to evenly distribute unprocessed pixel an error generated after follows the path of the curve was

performed toning. In the case of $\alpha = 1$, to obtain the same results as the method of diffusing only the next pixel of the curve path the error occurred after it follows a curved path, runs toning. This is the same method used in Figure 3, the problem does not occur in the video, but since the error is diffused only by the curved path, and is the same as the dithering a one-dimensional, with the brightness of the intermediate, a regular pattern is displayed many. Image applying the value of α between 0 and 1, it is seen from the display characteristics of both methods is changed continuously as if simultaneously applying the method of error diffusion of the two existing I could. It can be observed that in accordance with the value of α becomes larger, existing problems are resolved gradually. If the α value is 0.7 or more, I understood that the problem does not display most of the video quality at the same time will be better empirically. Further, it is possible to see the result of the value of α is smaller than 1, the regular pattern is also simultaneously reduced. Therefore, when using the values from 0.7 to 0.9, it is possible to obtain the best results.

α	Halftoning results
0.0	
0.1	
0.2	
0.3	
0.4	
0.5	
0.6	
0.7	



Figure 3. Halftoning results obtained by applying different α values to the Lena image

5. Conclusions

In this paper, the method of digital halftoning is diffused into neighboring pixels errors along the random space filling curves presented a new method for effectively solving the problems that may occur in a conventional manner. In [3], it is to solve the problem in a manner of diffusing an error only the next pixel of the pixel along the random space filling curve, it is currently processing. However, these methods, since the diffused error only one-dimensionally along the path, a regular pattern occurs frequently in the result image. In this paper, we introduce a method to simultaneously solve these problems interpolation so as to the error diffusion method for both. By doing so can be adjusted through the parameters α , a method of diffusing a method of uniformly diffusing into neighboring pixels, only the pixel to be processed in the following, depending on the value of α , continuous characteristics of both methods it is now possible to obtain visible results to. The use of the same path, there is a difference error is accumulated in response to the input image. In this paper proposes a method according to the cause, it is diffused into a single pixel, shows the experimental results. However, it is possible to see how to diffuse the error to a single pixel, and it is equivalent to the error diffusion one-dimensional along the scanning path, and to take full advantage of pixel structures adjacent to the two-dimensional, there is a limit unlikely. Expect to be able on the basis of the cause analysis of the problem in the future, it has been presented in this paper, better improved algorithm is presented.

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