

# A Novel Quadtree-Structured Scheme for Transmitting Chinese Calligraphy Progressively

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## Abstract

*Progressive image transmission (PIT) techniques are useful in Web applications. A user can get a rough preview of an image and decide if the entire detail of a picture needs to be transmitted, especially when the network bandwidth is restricted. In this paper, we propose a new progressive image transmission scheme for Chinese calligraphy. Because the colors used in Chinese calligraphy are very simple, we can apply the quadtree-structure to transmit the calligraphy progressively. The preliminary results show that transmitted bits can be saved in the first few rounds. The PSNR values in the first few rounds are much better than other PIT techniques.*

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## 1. Introduction

The Internet was designed for information sharing and communication. With the number of users growing on the Internet, more and more applications, such as digital museums, are being constructed on the Internet. However, the current Internet is not suitable for transmitting multimedia resources. Because the bandwidth of the current Internet is restrictive, multimedia resources cannot be transmitted fast enough. This situation limits an Internet user's ability to use applications on Web sites. To overcome this problem, a mechanism which allows adaptive transmission is needed. The progressive image transmission (PIT) technique [AG99], [CHC01], [CSC99], [CJC98], [CC94], [CC97], [JCC97], [KS96], [Tzo87] seems to provide such a solution. Instead of transmitting an entire picture bit-by-bit, PIT transmits the most significant portion of an image first, followed by less significant portions. Therefore, a receiver can quickly reconstruct a rough image according to the received bits. When more image bits are received, the clarity of the reconstructed image is changed from fuzzy to clear. For a Web application, a user can briefly look at the rough image before he/she decides whether to see the entire picture with better quality.

Typically, a good image transmission technique must meet the following requirements.

### 1. Smaller transmission load:

In order to shorten the transmission time of an image, the transmission load must be as small as possible. If we can distort the image within a visual tolerance to reduce the size of the image, the transmission load can be reduced, especially for those Web users using a network facility providing lower bandwidth.

### 2. Better image quality in the first few rounds:

To make it possible to decide quickly whether the received image is interesting, the quality of the transmitted image must be as good as possible in the first few rounds. If a rough image with good quality can be quickly reconstructed using the few bits received, a user can recognize the sketch of the image immediately before he/she decides whether to see a better quality of the image. Therefore, browsing time on the Web can be saved.

However, traditional PIT technologies are all designed for complex color images or gray level images. They are not adapted to Chinese calligraphies. Chinese calligraphy is a special kind of image in which ink concentration may be different. In general, we can

use black and white as the basic colors in calligraphy. Calligraphy is a treasure of Chinese culture. Chinese characters have been written in different styles and have been presented in all kinds of forms. It is not only practical but also a delicate work of art. Currently, several famous calligraphies have been prevented from being digitized by the museums holding them. Digital preservation has many advantages, such as information preservation and easy transmission over the Internet. Digital museums are a useful and practical application over the Internet. By building a digital museum, people can enjoy calligraphy on the Internet anywhere and at anytime without being limited by place and time. Therefore, how to develop an efficient and effective algorithm for the transmission and browsing of calligraphic images is an important issue in this case.

According to the properties of Chinese calligraphy, we developed an efficient progressive image transmission scheme for transmitting Chinese calligraphy to fulfill a user's demands. The proposed scheme is based on quadtree coding technology. The technology can not only represent an image efficiently but can also compress the quantity of an image. Quadtree technology is now being widely used in computer graphics, geographical information systems, and image representation. In this scheme, we first transfer a calligraphic image to a quadtree structure to make the information quantity of the image smaller and then transmit the image progressively. Our scheme provides a smaller transmission load and better image quality in the first few rounds. Thus, a receiver can efficiently view a calligraphy image over the Internet. According to the experimental results, the newly proposed solution meets the above two requirements and is superior to the *Bit Plane Method* (BPM) [Tzo87].

The rest of this paper is organized as follows. Before describing the proposed method, we will briefly review the technique of digital imaging, the data structure of a quadtree, and the most intuitive method, called the bit plane method, in progressive image transmission. The concept of a quadtree representation is described in Section 3. Then, we present the proposed scheme based on a quadtree structure in Section 4. Besides, examples of the proposed scheme are also given in the same session. In Section 5, our experimental results demonstrate the contribution. Finally, we draw some conclusions.

## 2. Related works

In this section, we shall briefly review the related works on progressive image transmission. First, we give an overview of the existing schemes in PIT. Then,

the simplest and most intuitive method for transmitting images progressively is introduced in this section.

Typically, the mechanisms and systems of progressive image transmission can be categorized into three categories: spatial domain [CHC01], [CSC99], [CJC98], [CC94], [CC97], [JCC97], transform domain [AG99], and pyramid-structured progressive transmission [KS96]. These methods often have a better image quality and a lower bit rate during transmission. However, most of these schemes employ complex transmission and reconstruction algorithms. Therefore, they require a longer execution time to encode and to reconstruct an image. The simplest and faster method for progressive image transmission in the spatial domain is the bit-plane method (BPM) [Tzo87]. BPM does not have any encoding processes and complex transmission/reconstruction algorithms. With this method, the transmitter transmits one bit for each pixel in each round from the most significant bit (MSB) to the least significant bit (LSB). The transmitted bits for all the pixels in each round is called a bit-plane. When a receiver receives either a '0' or a '1' for each pixel in the bit-plane, he/she can reconstruct each pixel using the mean as the predicted value. For instance, the image frame of a 256 gray-level image is shown in Figure 1. Each pixel of this gray-level image is represented by 8 bits. Thus, we can decompose the image to eight bit-planes in order from the MSB to the LSB.

157 (10011101)	165 (10100101)	231 (11100111)	189 (10111101)
183 (10110111)	178 (10110010)	193 (11000001)	186 (10111010)
78 (01001110)	84 (01100001)	105 (01101001)	99 (01100011)
61 (00111101)	57 (00111001)	158 (10011110)	167 (10100111)

**Figure 1:** *The original image*

Since the most significant bit is more sensitive to our vision, the receiver can quickly reconstruct a rough image. Therefore, the first bit-plane of the MSB will be first transmitted to the receiver. Figure 2 shows the first bit-plane of the original image. In this bit-plane, a bit value of '0' means that the range of the original pixel value is from 0 to 127, and a bit value of '1' means that the range of the original pixel value is from 128 to 255.

1	1	1	1
1	1	1	1
0	0	0	0
0	0	1	1

Figure 2: The first bit-plane of the original image

When the receiver receives the bit-plane bit by bit, a bit value of ‘0’ means that the original pixel value is less than 128. Conversely, a bit value of ‘1’ means that the original pixel value is greater than or equal to 128. Therefore, the mean of 0 to 127 is used to reconstruct the pixel values when the received bit value is ‘1’. Otherwise, the mean of 128 to 255 is used to reconstruct the pixel values when the received bit value is ‘0’. Thus, in the first round of BPM, the two values 64 and 192 are used to predict values to reconstruct the image. Figure 3 shows the reconstructed image frame in the first round.

192	192	192	192
192	192	192	192
64	64	64	64
64	64	192	192

Figure 3: The reconstructed image after the first round of BPM

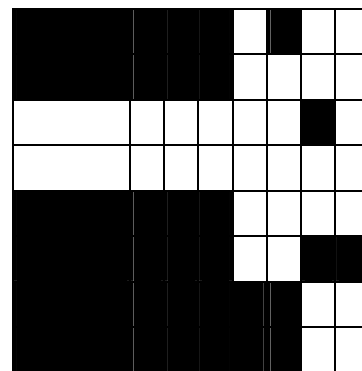
If the receiver needs a clearer image, the receiver uses the values 32, 96, 160, and 224 to reconstruct the image in the second round. More bit-planes can continue to be transmitted to the receiver until the receiver interrupts the transmission or until all the bit-planes are transmitted. Obviously, the transmission and reconstruction algorithm of BPM is very simple and easy to implement. However, the main disadvantage of BPM is high transmission load in each round.

In order to amend this problem, in this paper, we propose a new progressive image transmission method for transmitting calligraphy. Our method is based on a quadtree data structure. It does not only meet the two requirements of PIT, but it is also superior to the bit-plane method.

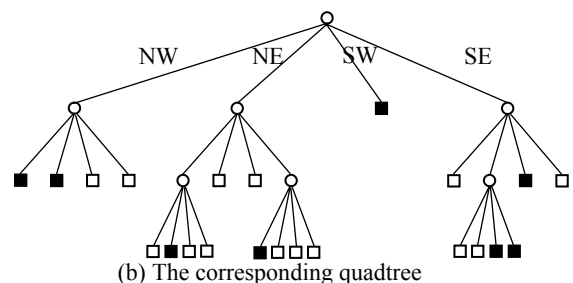
### 3. The quadtree representations

A quadtree, constructed by sequentially sub-dividing an image into four equal-sized sub-images, is a

hierarchical data structure for representing a binary image. A homogeneously colored sub-quadrant of the image can be represented by a leaf node on the tree alone. On the other hand, a heterogeneously colored sub-quadrant of the image is represented by an internal node. A leaf node that is black white is called a black or white node, respectively, and an internal node is called a gray node. The process of dividing each internal node into four sub-quadrants is repeated until each sub-quadrant has only one color. Then each sub-quadrant is further divided into four smaller sub-quadrants until each sub-quadrant has only one color. Figure 4 shows an example of the quadtree segmentation process. An original binary image with  $2^3 \times 2^3$  pixels is shown in Figure 4(a). First, we divide the original image into four equal sub-images, called NW, NE, SW, and SE. After that, we find that the sub-image SW has only one color. Thus, the corresponding node of SW becomes a leaf node and does not need to be divided anymore. Then, in the second round, we continue to divide the three sub-images NW, NE, and SE into four equal sub-quadrants. The process is repeated until all the sub-quadrants have only one color. Finally, the quadtree data structure for the original image is obtained, as shown in Figure 4(b).



(a) The binary image



(b) The corresponding quadtree

Figure 4: Example of the quadtree segmentation process

The Deep First (DF) search is a very popular representation of a quadtree structure. Using a DF-expression to represent the quadtree structure was first proposed by Kawaguchi and Endo in 1980 [KE80]. When an internal node is visited, the digit value '1' is used to represent it. On the other hand, once a leaf node is visited, the digit value '0' is used to represent it. In order to reconstruct the original image, the color information for each leaf node is also very important. For instance, we use '1' to represent the black leaf node and '0' to represent the white leaf node. Thus, the quadtree data structure in Figure 4(b) can be expressed as the bit string '11000011000000100000101000000'. In addition, the corresponding colors for all leaf nodes are '1100010000100010001110'. According to the two bit strings, we can easily reconstruct a lossless image.

#### 4. The proposed scheme

In order to present a work faithfully, we must store the image as a true color bit map file for digit liberation. That is, every pixel must be stored as a RGB value. Thus, an image may consume a large amount of memory space. In order to reduce the transmission time of a large file size, we transform the RGB image into a binary image. The steps in our method are explained below:

##### 4.1 Transform the Chinese calligraphy image into binary form

Because Chinese calligraphy is a special kind of image, it can be represented using only black and white colors. Thus, before transmitting an image, we are able to transform the true color image to a binary image having only black and white colors. Using the transformation matrix

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.523 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix},$$

we can transform every true color pixel to a gray scale value. For example, a RGB pixel value (123,55,211) is transformed to 93.116 ( $0.299 \times 123 + 0.587 \times 55 + 0.114 \times 211 = 93.116$ ). In this way, a true color can be transformed to a gray level image.

Next, we easily transform the gray level image to a binary image form. The simplest way is to define a threshold  $T$ . If the gray pixel value is bigger than the threshold value  $T$ , the corresponding pixel will be set to a white color and the bit value is set to 1. On the other hand, if the gray pixel value is smaller than the

threshold, the corresponding pixel will be set to a black color and the bit value is set to 0. This is done because the black pixel value in a gray level image is 0 and the white pixel value is 255. Thus, the mean of the two extreme pixel values can be used as the threshold.

##### 4.2 Progressive transmission

Before transmitting a calligraphic image progressively, we first apply the quadtree to represent the data structure of the transmitted image. Furthermore, we set up eight threshold values  $TH_1, TH_2, \dots, TH_8$  for each round, and these thresholds satisfy  $TH_1 < TH_2 < \dots < TH_8$ . Instead of dividing a quadrant into four equal sub-quadrants until all sub-quadrants have only one color, we modify the process so that when the percentage of black or white pixels is bigger than the threshold in each round, we stop dividing the quadrant.

Therefore, when a transmitter wants to transmit a calligraphic image to a receiver, he/she must do the following:

1. Compute the percentage of a quadrant with black or white pixels. If the black or white percentage of this quadrant is less than the threshold  $TH_1$  in the first round of the transmission cycle, divide the quadrant into four equal sub-quadrants. Repeat the quadrant dividing process until the black or white percentages in all the sub-quadrants are bigger than the threshold.
2. Similar to the quadtree representation that was described in Section 3, we need to give additional information for each leaf node in the constructed quadtree to record the color of this sub-quadrant. The rule for assigning the color information is very trivial. If the black pixels are bigger than the white pixels in a quadrant, we record the quadrant as black. Otherwise, we record the quadrant as white.
3. Transmit the corresponding bit string of the quadtree and the corresponding colors in the leaf nodes of the quadtree. The bit string of the quadtree can be expressed by the expression of the depth first search. For traversing the quadtree, the internal node could be expressed by a bit value of '1', meaning that the percentage of black or white pixels in the corresponding quadrant is not bigger than  $TH_1$ . The leaf node of the constructed quadtree could be expressed by a bit value of '0', meaning that the percentage of black or white pixels in the corresponding quadrant is bigger than  $TH_1$ . In addition, according to the order of the leaf

nodes, the corresponding color information can also be expressed by the other bit string for transmission to the receiver.

4. In the second round, the transmitter continues to compute the black or white percentage of a quadrant that corresponds to the leaf node in the first round. If the black or white percentage of this quadrant is less than the threshold  $TH_2$ , we deliver a bit value of '1' to announce that the leaf node will continue to be divided into four children. Similarly, the process will be repeated until the black or white percentages in all sub-quadrants are bigger than the threshold  $TH_2$ . Otherwise, we deliver a bit value of '0' to announce that the leaf node is still a leaf node in the round.
5. If the receiver wants to get better image quality in the next rounds, the transmitter repeats the process of the second round until all eight rounds are transmitted. The results of the remaining rounds are transmitted progressively.

Figure 5 shows the transmitted bits for three rounds of transmission. Take a  $1024 \times 1024$  image as an example. Suppose that the eight thresholds are 60%, 65%, 70%, 75%, 80%, 85%, 90%, and 95%. The data structure of the calligraphic image in each round can be expressed as shown in Figure 5. In the first round, we find that the percentages of all the leaf nodes are bigger than the first threshold. The transmitted bit strings are shown in Table 1, which includes tree node codes and color codes. In the second round, we continue to divide the leaf nodes with corresponding black or white percentages that are not bigger than the second threshold, namely 65%. Similarly, in the third round, we continue to divide the leaf nodes with corresponding black or white percentages that are not bigger than the third threshold 70%. Repeat the process until all black or white percentages of leaf nodes are bigger than the corresponding threshold. Table 1 shows the transmitted bit strings for each round.

### 4.3 Image reconstruction

When the receiver receives the tree node bit string and color bit string in each round, he/she can reconstruct the quadtree. According to the quadtree structure and the color bit string, the receiver can quickly reconstruct the calligraphic image. In the second round, a bit value of '1' means the node can be further divided into four sub-quadrants. Conversely, a bit value of '0' means the node is a leaf node. According to the reconstruction rules, we can reconstruct a rough image using only a small amount of transmitted data. When more image information is received, an image with a better quality will be displayed.

## 5. Experimental Results

This study focuses on the progressive transmission of calligraphic images. In our experiments, we applied BPM and our proposed schemes to the progressive image transmission of Chinese calligraphy. The experiments were divided into two parts. In the first part, we prepared two calligraphies, which are shown in Figure 6(a) and Figure 7(a) to show the reconstructed image in each round. In the second part, we used the same calligraphies to compare the transmitted bits between our proposed scheme and BPM. These test calligraphic images have a resolution of  $1024 \times 1024$  pixels.

The objective of the proposed scheme was to make the receiver get the image in the shortest time possible and with better image quality. Figures 6 and 7 are the reconstructed images in each round using our scheme. We can see that the user can get the sketches of the calligraphic images in the first few rounds. If, at this time, the user finds that the calligraphy is not interesting, he can immediately stop the transmission and make another choice. Otherwise, he can see a better quality of the image in the next few rounds.

In addition, we also applied both the BPM and our proposed method to progressive calligraphic image transmission. Table 2 shows the comparisons between our scheme and BPM. The transmitted quantities in the first round using our scheme for the two test calligraphies were 5.36 KB and 8.13 KB, respectively. However, the transmitted quantities in the first round using BPM for the two test calligraphies were 393.27 KB. We clearly find that the transmitted bits from our method for each round was significantly less than the one from BPM. Since the information was very limited during the proceeding runs, a rough calligraphic image was reconstructed quickly. Thus, the transmission of a useless image was avoided and the transmission time was greatly saved. In addition, after the final run, the image we got was very close to the original calligraphy within the visual tolerance, and the total number of transmitted bits was only about 4.7% of the original image size. According to the experimental results, we find that our proposed scheme is very practical and meets the requirements for PIT.

## 6. Conclusions

In this paper, we proposed a progressive calligraphic image transmission scheme based on the quadtree data structure. Our scheme applies the quadtree expression to effectively reduce the transmitted quantity. According to previous experiments, our schemes are very simple to implement and can significantly get

good image quality in the first few rounds. In particular, our scheme requires only 1.3%~2.1% transmitted quantity in the first round of BPM, and the total transmitted quantity in our scheme requires only 4.3%~4.7% of BPM. Therefore, the advantages of the newly proposed scheme include lower transmission bits and a reconstructed calligraphy with better image quality in the first few rounds of the transmission cycle. Practical use of the proposed scheme can be its application to a digital museum.

**Table 2:** The comparisons between our scheme and BPM of the transmitted quantities

Methods Rounds	Our Scheme		BPM
	Calligraphy A	Calligraphy B	
	Round 1	5.36KB	
Round 2	9.38KB	12.8KB	393.27KB
Round 3	13.3KB	15.42KB	393.27KB
Round 4	16.01KB	17.74KB	393.27KB
Round 5	20KB	20.94KB	393.27KB
Round 6	22.04KB	22.81KB	393.27KB
Round 7	23.39KB	24.04KB	393.27KB
Round 8	24.94KB	25.13KB	393.27KB
Total	134.42KB	147KB	3145.43KB

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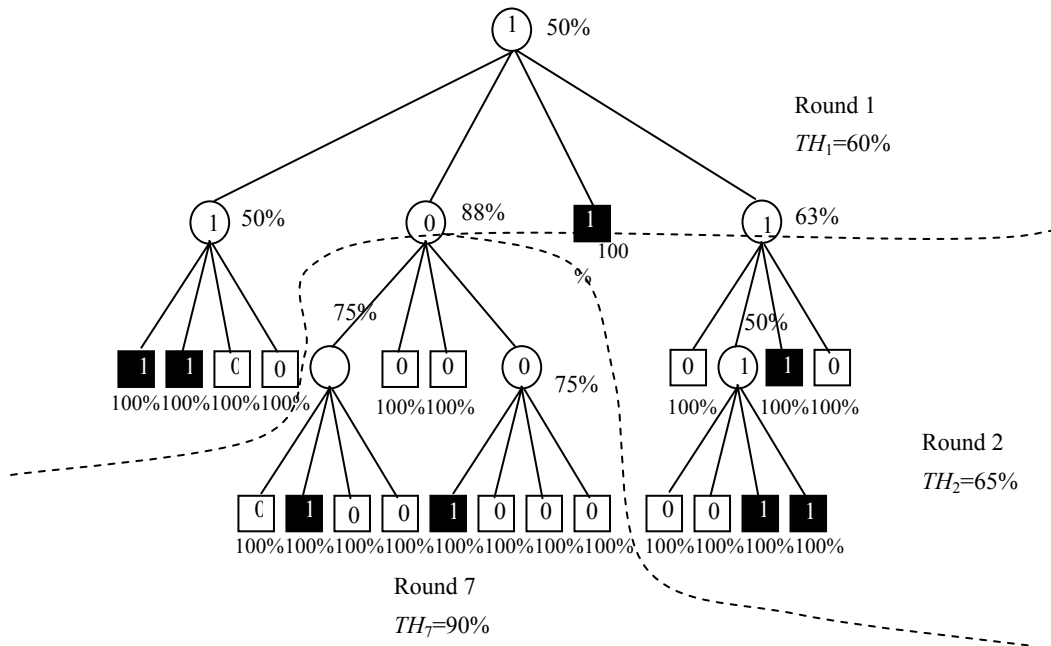


Figure 5: An example of progressively transmitting a corresponding quadtree of a calligraphic image

Table 1: The transmitted bit strings in rounds 1 to 8

Progressive transmission	tree node code (bits)	color code(bits)
Round 1 ( $TH_1=60\%$ )	110000000	1100011
Round 2 ( $TH_2=65\%$ )	000000101000000	0001110
Round 3 ( $TH_3=70\%$ )	000000000000000	
Round 4 ( $TH_3=75\%$ )	000000000000000	
Round 5 ( $TH_3=80\%$ )	000000000000000	
Round 6 ( $TH_3=85\%$ )	000000000000000	
Round 7 ( $TH_3=90\%$ )	0000100000000100000010000	0100001000
Round 8 ( $TH_3=95\%$ )	0000000000000000000000000	



Figure 6: The original calligraphy and reconstructed calligraphies in each round for the first test calligraphy using our scheme





**Figure 7:** The original calligraphy and reconstructed calligraphies in each round for the first test calligraphy using our scheme