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Generation of Twist Weaves from Right Circulant Matrices

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Abstract
Proposed here are some new methods for generating new kind of weaves entitled twist weaves from right circulant matrices. These weaves have similar structure as those of twill weaves however, they are quite different interlacement points. Generally, weave patterns are designed on a graph paper which is time consuming and requires a lot of efforts and patience. With the development of computer graphics, many software applications have been developed for designing weave patterns in a more convenient way as editing or error corrections can be done quite easily. However, drawing manually on computer using mouse still takes time and requires knowledge on weave designs. In this paper, we describe twist weave patterns which can be automatically generated from a right circulant matrix. Twist weave patterns have similar fabric structure like twill weaves but in different orientations. The are generally used in combination with twill weaves to generate other weave patterns such as diamond weaves, pointed twill weaves, sponge weaves etc. However, they have not been used or studied as a separate weave patterns. It is found that twist weave patterns can be generated from right circulant matrices. In this paper, the method of generating a right circulant matrix of any size desired size is given. Then, methods for generating twist weaves from the circulant matrix are described. Using these methods, twist weave patterns can be generated automatically in a much easier and faster way without needing to draw manually using mouse.
Keywords: *Circulant matrix, Left circulant matrix, Right Circulant matrix, Plain weaves, Twill weaves, Twist Weave patterns, Automatic Weave Pattern Generation.*

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I. INTRODUCTION

Weaving is as old as human civilization. It is mainly used in making clothes and other items such as baskets, mats etc. Weaving is the process or method of interlacement of warps and wefts to make a fabric. There are mainly three different ways of interlacements used in weaving known as plain, twill and satin and the patterns produced on a fabric are known as plain, twill and satin weaves. Many other different interesting weave patterns are formed by combination of these basic weave patterns. Of the three basic weave patterns, plain and twill weaves are quite popularly used in fabric designs. Plain weave is the simplest weave which can be easily designed in a loom having only two harnesses. For twill weaves, at least three harnesses looms are required. Twill is one of the three major types of textile weaves, along with satin and plain weaves. The distinguishing characteristic of the twill weave is a diagonal rib pattern. Twill weaves generally have high thread count, which make the fabric opaque, thick, and durable. Twill weaves find a wide range of application such as drill cloth, khaki uniforms, denim cloth, blankets, shirtings, hangings and soft furnishings. In [4,6], basic twill weaves and their applications are given. Traditionally, these weave patterns are created by filling the grid or cells on a graph paper. But with the development of computer graphics applications, creating weave patterns can be done in a computer. There are many software applications available to enable a user to create weave design. As compared to designing on a graph paper, designing using a software application is more flexible, error free and easy to edit and update. Some of the popularly used software applications for creating weave patterns are given in [1, 5, 7]. However, creating weave patterns in a computer still requires time and efforts to manually fill the grids of a digital sheet by manually clicking them correctly. In [8, 9, 10], methods for generating plain, twill and satin weaves from left circulant matrices have been provided. In this paper, we will be discussing on how to automatically generate weave patterns from circulant matrices.

Circulant matrices are matrices which are generated from a single row or a column vector. Usually, circular matrices have certain regular patterns as we have patterns in weaves. There are two types of circular matrices depending on in which directions the successive rows are shifted to generate the circular matrix. If successive rows are sifted towards left then they are called left circulant matrices. On the other hands, if the successive rows are shifted towards right, they are called right circulant matrices. More on circulant matrices and their applications can be obtained from [2,3]. In this paper, we will be using right circulant matrices for generation of new weave patterns entitled twist weave patterns as these weave patterns have similar to twill weave patterns but not exactly the same. That is, twist weaves can be considered as different variants of twill weave. In section II, different ways of generating right circulant matrices are given. Also, the relationship between the left and right circulant matrices are given. In Section III, generation of various types of twist weaves from right circulant matrices are given along with algorithm and Scilab code. In Section IV, different types of twist weaves generated from the right circulant matrices are provided as experimental results and Conclusions is given in Section V.

II. GENERATION OF RIGHT CIRCULANT MATRIX

Circulant matrices are matrices which are generated from a given row or column by shifting it towards left (anti-clockwise) or right (clock-wise) direction. Usually, a circulant matrix is a square matrix generated by successive shifting of a row vector in each row. First row is the given row vector, second row is obtained by circular shifting the first row by one element. Third row is obtained by circular shifting of the second row by one element. That is, each row is obtained by circular shifting of the previous row by one-element.

Suppose, $\boldsymbol{c} = [c_0, c_1, c_2, c_3, \dots, c_{N-1}]$ is a row vector having N elements. Then, a right circulant matrix C can be generated from the row vector $\boldsymbol{c}$ by circularly shifting each element on the right by one position in each successive row. Following is the right circulant matrix generated from the row vector $\boldsymbol{c}$.

$$C = \begin{bmatrix} c_0 & c_1 & c_2 & c_3 & \dots & c_{N-1} \\ c_{N-1} & c_0 & c_1 & c_2 & \dots & c_{N-2} \\ c_{N-2} & c_{N-1} & c_0 & c_1 & \dots & c_{N-3} \\ & \dots & \dots & \dots & & \\ & \dots & \dots & \dots & & \\ c_1 & c_2 & c_3 & c_4 & \dots & c_{N-1} \; c_0 \end{bmatrix}$$

From the right circulant matrix, it may be observed that all elements parallel to the diagonal elements are the same. If we carefully observe, it can be seen that elements in a particular row are not the same as the elements in the corresponding column unlike the case in left circulant matrix. That is, the elements in the first row are not the same as elements in the first column, elements in the second row are not the same as the elements in the second column and so on. In other words, a right circulant matrix is not a symmetric matrix like a left circulant matrix.

To know more about the relation of columns and rows in a right circulant matrix, let us consider a right circulant matrix of size 4x4 as shown below.

$$\begin{bmatrix} c_0 & c_1 & c_2 & c_3 \\ c_3 & c_0 & c_1 & c_2 \\ c_2 & c_3 & c_0 & c_1 \\ c_1 & c_2 & c_3 & c_0 \end{bmatrix}$$

It may be seen that the last column in the above circulant matrix is the vertically flipped version of transpose of the last first row. The third column is the vertically flipped version of the transpose of the second row. The second column is the vertically flipped version of the transpose of the third row and the first column is the vertically flipped version of the transpose of the fourth (i.e., last) row.

In general, we can express the relation between the rows and columns in a right circular matrix as

kth column=vertical flip(transpose of (N-1-k) row)

kth row=horizontal flip(transpose of(N-1-k) column)

Where N is the no. of rows or columns in a right circular matrix and k has the range 0 to N-1.

The relation between the elements of row vector $\boldsymbol{c}$ and circulant C can be established as follows.

$$\mathrm{C[i,j]} = \boldsymbol{c}[(\mathrm{N} - \mathrm{i} + \mathrm{jj})\%\mathrm{N}]$$

Where i, j=0, 1, 2, …, N-1 and % denotes the modulus operator.

The above relation can be easily implemented in a programming language supporting 0-offset arrays using two For loops.

```
For i=0 to N-1
        For j=0 to N -1
                C(i,j)=c((N-i+j)%N);
        End
End
```

For designing weave patterns, we are interested to have a circulant matrices whose elements are in a range natural number such as 0 to 9, 0-15 etc. Such a circulant matrices can be generated from an array or row vector whose elements are x=[0,1,2,3,4,5,6,7,8,9]. As the content of the arrays are known, we can simply specify the largest element in the array, such as 9 which indicates a circulant matrix of size 10x10 with elements 0 to 9. So, we can have another algorithm to generate a right circulant matrix of a specific size given a positive number as its input N.

Following is the algorithm to generate circulant matrix of size N whose elements are 0 to N-1.

```
For i=0 to N-1
        For j=0 to N-1
                C(i,j)=(N-i+j)%N;
        End
End
```

These two algorithms, i.e., algorithm to generate a right circulant matrix from a given array and the algorithm to generate a right circulant matrix from a given number, can be combined to generate a left circulant matrix given regardless of whether an array is given as input or just a number as input. Scilab code for generating right circulant matrix of any desired size is given in Figure-1 in which the input can be row vector or a scaler. If a row vector is given as input, the right circulant matrix is given by the circularly shifting the vector right in each successive rows as given in the algorithm. If the input is a scalar number n, then, it generates a right circulant matrix from elements 0 to n-1. The outputs of the Scilab function rightcirc for generating a right circulant matrix of size 8 given a number and a vector as input are shown respectively in Figure-2 and Figure-3.

```
function y=rightcirc(x)
  // x is a row  vector or a number
  n=length(x);
  if n==1 then
    for i=0:(x-1)
      for j=0:(x-1)
        y(i+1,j+1)=modulo(x+i-j,x);
      end
    end
  else
    for i=0:n-1
      for j=0:n-1
        y(i+1,j+1)=x(1+modulo(N+i-j,n));
      end
    end
  end
endfunction
```

Figure-1: Code for generating right circulant matrix

```
--> y=rightcirc(8)
 y  =

   0.   1.   2.   3.   4.   5.   6.   7.
   7.   0.   1.   2.   3.   4.   5.   6.
   6.   7.   0.   1.   2.   3.   4.   5.
   5.   6.   7.   0.   1.   2.   3.   4.
   4.   5.   6.   7.   0.   1.   2.   3.
   3.   4.   5.   6.   7.   0.   1.   2.
   2.   3.   4.   5.   6.   7.   0.   1.
   1.   2.   3.   4.   5.   6.   7.   0.
```

Figure-2: Output of a rightcirc function given 8 as input

```
--> y=rightcirc([0 1 2 3 4 5 6 7])
 y  =

   0.   1.   2.   3.   4.   5.   6.   7.
   7.   0.   1.   2.   3.   4.   5.   6.
   6.   7.   0.   1.   2.   3.   4.   5.
   5.   6.   7.   0.   1.   2.   3.   4.
   4.   5.   6.   7.   0.   1.   2.   3.
   3.   4.   5.   6.   7.   0.   1.   2.
   2.   3.   4.   5.   6.   7.   0.   1.
   1.   2.   3.   4.   5.   6.   7.   0.
```

Figure-3: Output of rightcirc function given a 1-d array as input.

Plain Weave Generation from a right Circulant Matrix

Plain weave is the weave in which warp and weft threads are interlaced alternately. In matrix form, it is represented by a matrix having elements of alternate 0s and 1s. So, plain weave of desired size can be obtained by finding the remainder of 2 of right circulant matrix or left circulant matrix. Figure-4(a) shows the plain weave matrix generated from a right circulant of size 8 of figure-3 and the corresponding weave graph is shown in Fig. 4(b).

$$P = \begin{bmatrix} 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \end{bmatrix}$$

Figure-4(a): Plain weave matrix

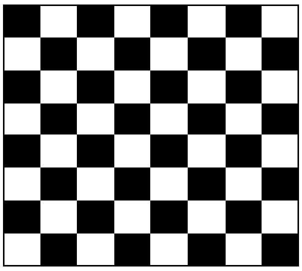


Figure-4(b): Plain weave graph of Figure-4(a).

III. TWIST WEAVE PATTERN GENERATION FROM A RIGHT CIRCULANT MATRIX

Twist weaves have similar weave structure with twill weaves one of the popular basic weave patterns used in fabric designs. Like twill weaves, twist weaves also have specific number of ups and down numbers sum of which determines the repeat size. The pattern in a twist weave depends on the number of ups and downs of warps in a given repeat size. The minimum repeat size for a twist weave is 3 corresponding to 2/1 (2 up and 1 down) or 1/2 (1 up 2 down) twist weave. Figure-5(a) shows the 2/1 twist weave matrix of size 9x9 in which 0s' represent the ups and 1s' represent the downs of warps. This is because warps are generally represented by black vertical lines and wefts are represented by white horizontal lines. The repeat size is 3 marked in orange color in the figure. The corresponding weave graph is shown in Figure-5(b) in which the ups are marked in black (0s) and downs are in white (1s). For repeat size of 3, only two different twist weaves are possible i.e., 2/1 and 1/2 twist weaves. These two weaves are interrelated, i.e., one once a 2/1 weave matrix is obtained, the 1/2 weave matrix can be obtained from it. Figure-6(a) shows a 1/2 twist weave matrix and its corresponding weave graph is shown in Figure-6(b). For a twist weave of larger repeat size, there are three or more variants having the same repeat size. For example, for a twist weave repeat size of 8, the possible variants are 1/7, 7/1, 2/6 , 6/2, 3/5, 5/3, 4/4, i.e., there are seven variants of twist weaves having the repeat size 8. Twist weave patterns having the different number of ups and downs numbers are known as unbalanced twist weaves. If the number of ups and downs are the same, the twill weave are known as balanced twist weaves. The unbalanced twist weaves have different back and front patterns in the fabric. For balanced twist weaves both sides of the fabric have similar weave patterns.

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

Figure-5(a): 2/1 twist weave of size 9x9

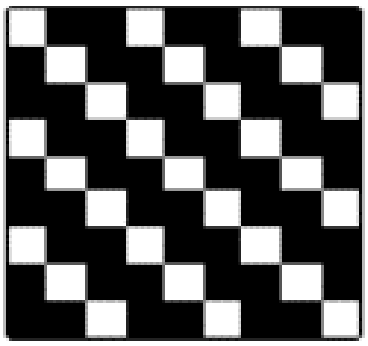


Figure-5(b): weave graph of 2/1 twist weave

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

Figure-6(a): 1/2 Twist weave matrix

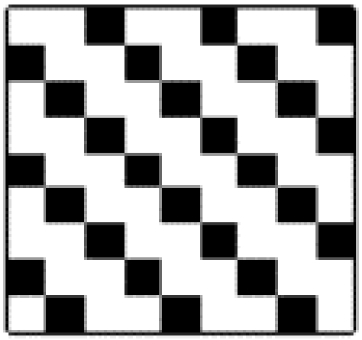


Figure-6(b): Graph of 1/2 Twist Weave

It may be seen that from figures 5 and 6 that twist weaves have black and white rib lines parallel to the diagonal line. The same is true for a right circulant matrix. So, it is convenient to generate the twist weaves from the right circulant matrix of appropriate size. To generate a twist weave of specific ups and down lines from a right circulant matrix, we need to appropriately make zeros corresponding to the up numbers and ones corresponding to the down numbers. To understand the process of generation twist weave from a right circulant matrix, let us generate a balanced twill weave of repeat size 4 having 2 ups and 2 downs, i.e., 2/2 twist weave of size 8. For this, we need to create a left circulant matrix X of size 8x8. Then, we need to make two zeros' lines followed by two ones' lines parallel to the off-diagonal line. The elements in off-diagonal line of X are 7. So, to make zero lines parallel to off-diagonal line starting from it, we need to make elements 6 and 7 zeros and elements 4 and 5 ones for two lines of ones parallel to the off-diagonal line. But the repeat size of twill weave is 4, so the elements in the matrix can be made 0 to 3 by finding the remainder of 4 to get matrix X'. Make the elements 2 and 3 zeros and 0 and 1 ones to get the 2/2 twill weave matrix T. When we divide X' by 2, we will get 0s as quotients for 0 and 1 elements and 1s as quotients for 2 and 3 elements. This can be achieved by flooring operation. Inverting the result will give us the twill matrix T. Figure-7 shows the steps for generating a twill weave from a left circulant matrix.

$$X = \begin{bmatrix} 0 & 1 & 2 & 3 & 4 & 5 & 6 & 7 \\ 7 & 0 & 1 & 2 & 3 & 4 & 5 & 6 \\ 6 & 7 & 0 & 1 & 2 & 3 & 4 & 5 \\ 5 & 6 & 7 & 0 & 1 & 2 & 3 & 4 \\ 4 & 5 & 6 & 7 & 0 & 1 & 2 & 3 \\ 3 & 4 & 5 & 6 & 7 & 0 & 1 & 2 \\ 2 & 3 & 4 & 5 & 6 & 7 & 0 & 1 \\ 1 & 2 & 3 & 4 & 5 & 6 & 7 & 0 \end{bmatrix}$$

Step-a

$$X' = (X\%4) = \begin{bmatrix} 0 & 1 & 2 & 3 & 0 & 1 & 2 & 3 \\ 3 & 0 & 1 & 2 & 3 & 0 & 1 & 2 \\ 2 & 3 & 0 & 1 & 2 & 3 & 0 & 1 \\ 1 & 2 & 3 & 0 & 1 & 2 & 3 & 0 \\ 0 & 1 & 2 & 3 & 0 & 1 & 2 & 3 \\ 3 & 0 & 1 & 2 & 3 & 0 & 1 & 2 \\ 2 & 3 & 0 & 1 & 2 & 3 & 0 & 1 \\ 1 & 2 & 3 & 0 & 1 & 2 & 3 & 0 \end{bmatrix}$$

Step-b

$$T = 1 - \left\lfloor \frac{X}{2} \right\rfloor = \begin{bmatrix} 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 \\ 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 \end{bmatrix}$$

Step-c

Figure-7: Steps to get twist weave matrix from a right circulant matrix

Steps in Figure-7 are summarized below.

Step-a: Generate a left circulant matrix X of appropriate size.
Step-b: Find the remainder of X when divided by 4 to get X'
Step-c: Invert the matrix obtained by flooring when X' is divided by 2 to get the twist matrix T

The method given in Figure-7 can be used to generate a balanced twill weave. However, for generating unbalanced weaves, we need to do some necessary modification to make parallel lines of zeros and ones for different ups and downs number of the unbalanced twill weaves.

Algorithm for generation of Twist weave:

1. Get the number of ups and downs for a twist weave
2. Determine the repeat size as the sum of ups and downs
3. Generate the right circulant matrix C of size 2 to 3 times the repeat size
4. Find the remainder Cr of the circulant matrix when divided by the repeat size

5. Find the flooring of the remainder matrix when divided by the downs number
6. Inverse the matrix in step-5 by subtracting it from 1 and make all negative values to 0.
7. Display the matrix in step-6 as image.

The above algorithm is a generalized one in the sense that it can be used for generating balanced and unbalanced twist weaves. In the above algorithm, when we divide the circulant matrix by a small down number, some of the quotients become greater than 1 in step-5 which when subtracted from 1 result in negative values in step-6 which correspond to 0 lines. So, it is necessary to make zeros for all negative values in Step-6. Such negative values do not occur when the down number is greater than or equal to ups numbers. Following is the Scilab code for generating twist weave.

```
function y=twist(m, u, d)
  rp=u+d;
  y=rightcirc(m);
  y=1-floor(modulo(y,rp)/d);
  y(y<0)=0;
endfunction
```

Using this twist function, we can generate the balanced and unbalanced twist weave matrices of any desired size. Figure-8(a) show the unbalanced 3/2twist weave graph corresponding to a weave matrix generated using the twist(10,3,2). Similarly, Figure-8(b) shows the 2/3 twill weave generated using twist(10, 2, 3).

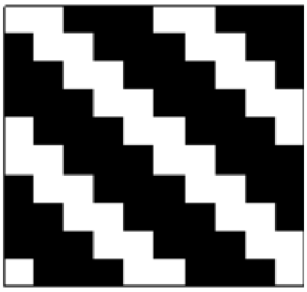


Figure-8(a): 3/2 Twist weave

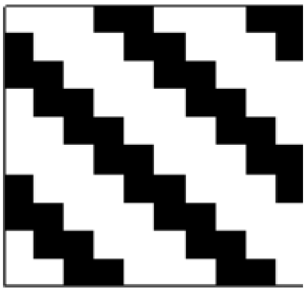


Figure-8(b): 2/3 Twist weave

Generation of Z-Twill Weaves:

The twist weaves discussed or generated so far having rib lines parallel to diagonal lines which can be known as S-Twist weaves. There may also be twist weaves which have rib lines parallel to off-diagonal lines. Such twist weaves are may be known as Z-twist weaves. For drawing Z-Twist weaves, drawing starts from the top of the left end. These two weave types i.e., Z-twist and S-twist are the reflected images of each other. That is, Z-twist weaves are obtained by flipping the S-twist weaves in the left-right direction.

If Y is a weave matrix of u/d S-twist weave, then u/d Z-Twill weave matrix W, can be generated in Scilab using the following command for performing flipping left-right direction.

```
W=filpdim(Y,2);
```

So, we do not need separate program code for generating Z-twist weaves. The same twist function given for generating S-twist weave will first be used which will be followed by flipping along the second dimension, i.e., along columns. Figure-9(a) shows the 3/2 S-twist weave and the corresponding 3/2 Z- twist weave is shown in Figure-9(b).

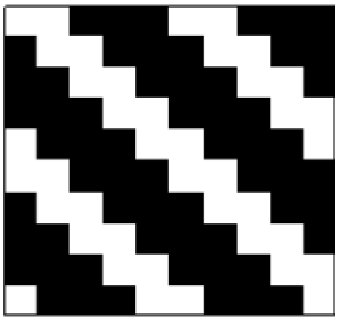


Figure-9(a): 3/2 S- twist weave

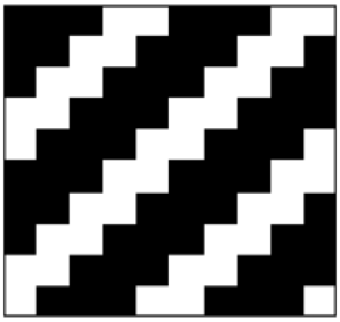


Figure-9(b): 3/2 Z-twist weave

Combining Z and S twill weaves in different ways, different interesting weave patterns such as herring bone weave, diamond weaves etc. can be created. Moreover, we can combine plain weaves together with twist weaves to generate more and more interesting weave patterns.

IV. EXPERIMENTAL RESULTS

To test the methods of generating plain and twist weaves from the right circulant matrices, we apply the functions given in the paper on various types and size of weaves. It is found that circulant matrix can be used without many problems for generating weave matrices of size up to 3 times the repeat size. If weave matrix size of a twill weave is more than 3 times the repeat size, it gives extra rib lines giving wider rib line of 1s or 0s. This is really not a problem as twist weaves are drawn basically for a repeat size. Both S and Z- twist weaves of any size can be generated using the twist weave function.

To show the difference between twill and twist weaves, we give all possible twill weaves and twist weaves of repeat size 8 which is repeated thrice to get weave patterns of size 24 x 24 so that weave patterns can be visualized well. It must be noted that in twill weaves are generated from left circulant matrices and generation process starts from the left bottom corner. The twill weaves generated in this way are Z-twill weaves and to get S-twill weaves, Z-twill weaves are flipped left to right. On the other hand, twist weaves are generated from the right circulant matrices and the generation starts right top corners. The generated twist weaves are S-twist weaves and Z-twist weaves are generated from flipping the S-twist weaves left to right.

Table-1 shows the weave graphs of S and Z twill weaves of repeat sizes 8. First row of the table shows the possible unbalanced and balanced Z-twill weave patterns for a repeat size of 8. It may be noted that only the 4/4 is the balanced twill weave for repeat size-8. Similarly, all possible S-twill weaves having repeat size 8 are shown in the second row. In a balanced twill weave, the width of the black and white rib lines in the twill weaves are equal. In unbalanced twill weaves, the widths of the black and white rib lines are different.

Table-2 shows the weave patterns which can be formed by Twill weaves of repeat size 8. These weaves have parallel rib lines similar to twill weaves but they are different. There are 7 possible twist weaves for repeat size 8, out of which 6 weaves are unbalanced twist weaves and 1 is balanced twist weaves. That is, only 4/4 twist weave is the balanced twist weaves while remaining 6 weaves are unbalanced twist weaves. The twist weaves given in the first row are S-twist weaves which are directly generated from the right circulant matrices. The weaves in the second row are Z-twist weaves generated by horizontal flipping of the weaves in the first row.

Table-1: Twill weaves for repeat size 8

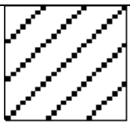
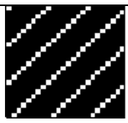
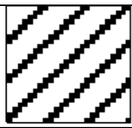
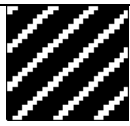
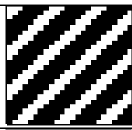
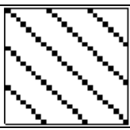
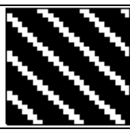
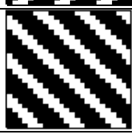
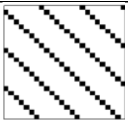
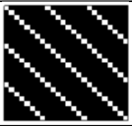
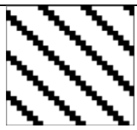
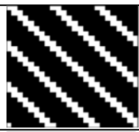
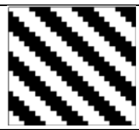
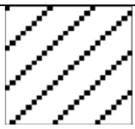
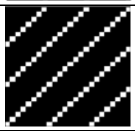
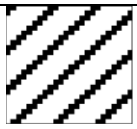
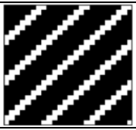
Type	1/7	7/1	2/6	6/2	3/5	5/3	4/4
Z-Twill							
S-Twill							

Table-2: Twist weaves of repeat size 8

Type	1/7	7/1	2/6	6/2	3/5	5/3	4/4
S-Twist							
Z-Twist							

From the weaves patterns of Twill and Twist weaves in Table-1 and Table-2, it could be seen that the Z -twill weaves and Z-twist weaves are significantly different although they have similar rib lines. In 5/3 Z- twill weave, the top left corner has 6 whit pixels, while the top left corner of 5/3 z-twist has 15 black pixels. The bottom right corner of the 5/3 Z-twill has 10 black 10 pixels while bottom right corner of the 5/3 Z-twist weave has 3 white pixels. Similar is the case for S-twill and S-twist weaves. Many more interesting weave patterns such as herringbone weaves, diamond weaves etc. can be formed by combining S and Z-twist weaves given in Table-1 and 2.

V. CONCLUSION

In this paper, we describe about right circulant matrices can be used for generation of twill like weaves entitled twist weaves. Two different ways of generating right circulant matrices, i.e., generating a right circulant matrix from a vector (1-dimensional array) and a given number specifying only the size. Circulant matrices that are generated from a given number are formed by circular shifting of natural numbers and are more suitable for generating weave patterns. Some effective ways of generating plain and twist weave patterns from right circulant matrices are also described. Using these methods, we can easily generate different twist weave pattern of desired size in a much faster way which will save significant amount of time and efforts for manually drawing the patterns. It has been tested for various types and sizes of balanced and unbalanced twist weave patterns. All twist weave patterns can be generated as expected. Similar to twill weaves, twist weaves can be used to generate many different derivative patterns such as herringbone, diamond weaves etc.

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