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Generation of Twest Weaves from Down Circulant Matrices

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Abstract
Proposed here are some new methods for generating new kind of weaves entitled twest weaves from down circulant matrices. On study, we found that weave patterns follow certain repetition which can be expressed using circulant matrices. Plain weaves, twill weaves and satin weaves can be generated from the left circulant matrices. New types of weave patterns called twist weaves can also be generated from the right circulant matrices. In this paper, we describe generation of another new weave patterns called twest weave patterns from down circulant matrix. Twest weave patterns have similar fabric structure like twill and twist weaves but in different orientations. They 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. In this paper, the method of generating a down circulant matrix of any size desired size is given. Then, methods for generating twest weaves from the down circulant matrix are described. Using these methods, twest 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, Down-circulant matrix, Plain weaves, Twill weaves, Twist weaves, Twest Weaves, Weave patterns, Automatic Weave Pattern Generation.*

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I. INTRODUCTION

Textile weaves are created by using the methods of interlacement of warps and wefts to increase the look and feel of a fabric. There are three different basic weave patterns we generally use to make a fabric. They are plain weave, twill weave 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 this paper, we will be discussing on how to automatically generate plain and twill weaves 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 gave 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]. Left circulant matrices can be conveniently used for the generation of basic twill weaves [8,9,10]. It has been found that a variant of twill weaves entitled twist weaves can be generated from right circulant matrices [11]. In this paper, we will be using down circulant matrices for generation of new weave patterns entitled twest weave patterns as these weave patterns have similar to twill and twist weave patterns but not exactly the same as regards orientation. That is, twist weaves can be considered as different variants of twill or twist weave. In section II, different ways of generating down circulant matrices are given. Also, the relationship between the left and right circulant matrices are given. In Section III, generation of various types of twest weaves from down circulant matrices are given along with algorithm and Scilab code. In Section IV, different types of twest weaves generated from the down circulant matrices are provided as experimental results and Conclusions is given in Section V.

II. GENERATION OF DOWN 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. It has been found that circularly shifting the column down by one element, we can get a different circulant matrix which we can call a down-circulant matrix.

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

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

From the down circulant matrix, it may be observed that all elements parallel to the diagonal elements are the same. If we carefully observe, it can also 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 down circulant matrix is not a symmetric matrix like a left circulant matrix.

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

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

It may be seen that the last column in the above circulant matrix is the vertically flipped version of transpose of the 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 down 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 0-offset down circular matrix.

By slightly modifying the relation, we can obtain down circulant matrix from a column $\boldsymbol{c}$ as follows.

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

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 column 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 down circulant matrix of a specific size given a positive number as its input N.

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

```
function y=downcirc(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 down circulant matrix

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

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

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

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

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

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

Plain Weave Generation from a Down 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 down circulant matrix or natural circulant matrix. Figure-4(a) shows the plain weave matrix generated from the down circulant of size 8 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

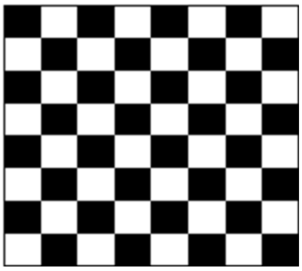


Figure-4(b): Plain weave graph of Figure-4(a).

III. GENERATION OF TWEST WEAVE FROM A DOWN CIRCULANT MATRIX

Twest weave has similar weave structure like twill weave which is one of the popular basic weave patterns used in fabric designs. It has many desired characteristics for generation of weave patterns. Every weave pattern has a repeat size replicating which multiple times generates a fabric. Like twill weaves, twill weaves have specific number of ups and down numbers sum of which determines the repeat size. The pattern in a twill weave depends on the number of ups and downs in a given repeat size. The minimum repeat size for a twest weave is 3 corresponding to 2/1 (2 up and 1 down) or 1/2 (1 up 2 down) as in twill weave. Figure-5(a) shows the 2/1 twest weave matrix of size 9x9 in which 0s' represent the ups and 1s' represent the downs of warps. The repeat size is 3 marked in orange color. 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 twill weaves are possible i.e., 2/1 and twest weaves. These two weaves are interrelated, i.e., 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 twill weave matrix and its corresponding weave graph is shown in Figure-6(b). For a twill weave of larger repeat size, there are three or more variants of twill weave having the same repeat size. For example, for a twill 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 twill weaves having the repeat size 8. Twill weave patterns having the different number of ups and downs numbers are known as unbalanced twill weaves. If the number of ups and downs are the same, the twill weave are known as balanced twill weaves. The unbalanced twill weaves have different back and front patterns in the fabric. For balanced twill 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 Twest weave of size 9x9

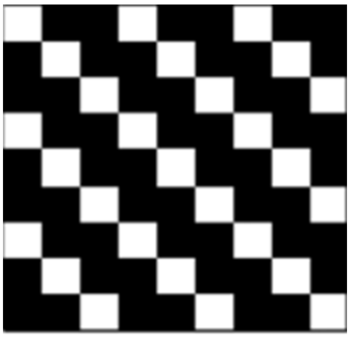


Figure-5(b): weave graph of 2/1 Twest weave

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

Figure-6(a): 1/2 Twest weave

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

It may be seen that from figures 5 and 6 that twest weaves have black and white rib lines parallel to the diagonal line. The same is true for a down circulant matrix. So, it is convenient to generate the twest weaves from the down circulant matrix of appropriate size. To generate a twest weave of specific ups and down lines from a down circulant matrix, we need to appropriately make zeros corresponding to the up numbers and ones

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

Step-a

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

Step-b

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

Step-c

corresponding

Figure-7: Steps to get twest matrix from a down circulant matrix

to the down numbers. To understand the process of generation of twest weave from a down circulant matrix, let us generate a balanced twest weave of repeat size 4 having 2 ups and 2 downs, i.e., 2/2 twest weave of size 8. For this, we need to create a down circulant matrix X of size 8x8. Then, we need to make two zeros' lines followed by two ones' lines parallel to the diagonal line. The elements in diagonal line of X are 0. So, to make zero lines parallel to 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 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 twest 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 twest matrix T. Figure-7 shows the steps for generating a twill weave from a down circulant matrix.

Steps in Figure-7 are summarized below.

Step-a: Generate a down 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 twill 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 modifications to make parallel lines of zeros and ones for different ups and downs number of the unbalanced twest weaves.

Algorithm for generation of Twill weave:

1. Get the up/down numbers of a twest weave
2. Determine the repeat size
3. Generate the down 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 twill 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 twill weave.

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

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

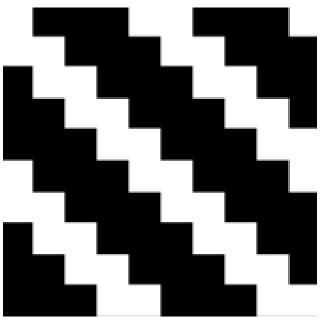


Figure-8(a): 3/2 Twest weave

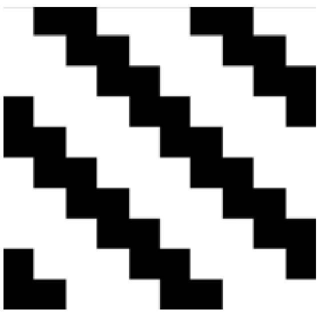


Figure-8(b): 2/3 Twest weave

It can be seen from the figures that the twest weaves are different from the corresponding 3/2 and 2/3 twill and the twist weaves. These twest weaves can be considered as S-twest weaves as the white and the black lines are parallel to the diagonal line.

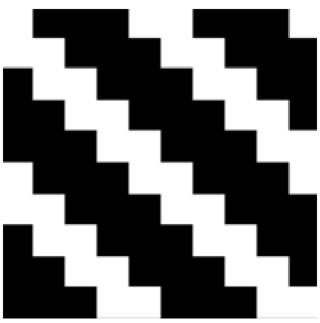
Generation of Z-Twest Weaves:

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

If Y is a weave matrix of u/d S-twest weave, then u/d Z-Twest 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-twill weaves. The same twest function given for generating S-twest 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-twest weave and the corresponding 3/2 Z-twest weave is shown in Figure-9(b).



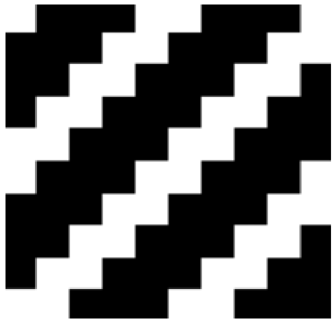


Figure-9(a): 3/2 Z twest weave Figure-9(b): 3/2 S-twest weave

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

IV. EXPERIMENTAL RESULTS

Twest weaves are the weaves which can be conveniently generated from the down circulant matrices. From the dow circulant matrices, we can easily generate plain weave as well. To test the methods of generating plain and twest weaves from the down circulant matrix, we apply the functions given in the paper on various types and sizes of weaves. Both S and Z- twest weaves of any size can be generated using the twill weave function.

Table-1 shows the weave graphs of S and Z twest weaves of repeat sizes 6. First row of the table shows the possible unbalanced and balanced S-twest weave patterns of size 12-by-12. It may be noted that only the 3/3 is the balanced twest weave for repeat size-6. The twest weaves having greater number of ups has thicker black lines than white lines. The twest weaves having greater down lines have thinner black lines than the white lines. Similar is the case for Z-twest weaves. All possible Z-twest weaves having repeat size 6 are shown in the second row.

Table-2 shows the weave patterns which can be formed by additively combining Twest weaves given in Table-with basket weave (which is a kind of plain weaves) of corresponding size. Using basket weaves the interlacement patterns are getting sparse. It may be seen that interesting weave patterns could be obtained by combining the twest weaves and the basket weaves. The generated weaves are quite different from the constituent weaves, i.e., the twest weaves and basket weaves. However, these weaves have rib lines along the rib lines of the corresponding twest weaves. That is, the generated weaves in the first row of Table-2 have rib lines parallel to the diagonal line whereas the weave patterns in the second row have rib lines parallel to the off-diagonal lines as they are generated from the Z-twest weaves. These makes the weaves pattern more dense rib lines as compared to the pure twill weaves.

Table-1: Twill weaves for repeat size 6

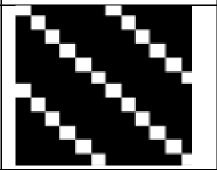
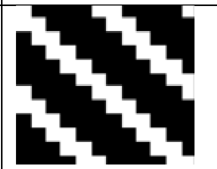
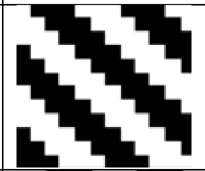
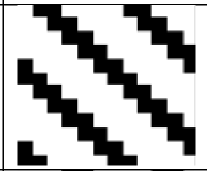
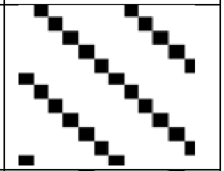
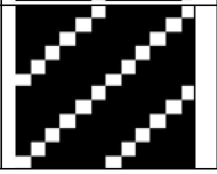
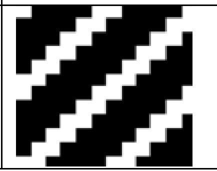
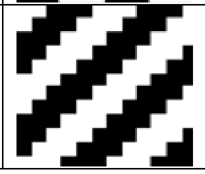
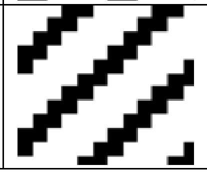
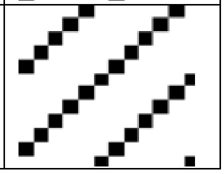
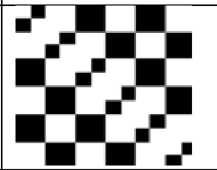
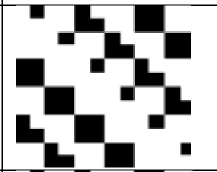
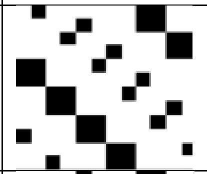
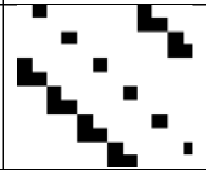
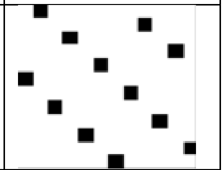
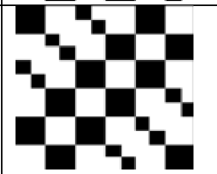
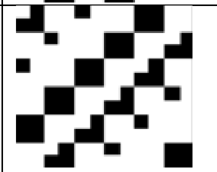
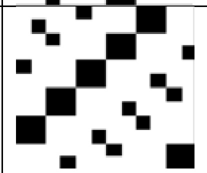
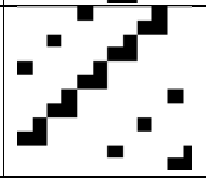
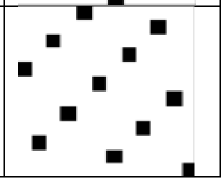
Type	5/1	4/2	3/3	2/4	1/5
S-Twest					
Z-Twest					

Table-2: Twill weaves combined plain weaves

Type	1/5	2/4	3/3	4/2	5/1
S-Twest					
Z-Twest					

Many more interesting weave patterns such as herringbone weaves, diamond weaves etc. can be formed by combining S and Z-twest weaves given in Table-1 and 2 with many other weaves.

V. CONCLUSION

In this paper, we describe about circulant matrices and methods for generating down circulant matrices. Two different ways of generating down circulant matrices, i.e., generating a down circulant matrix from a vector (1-dimensional array) and generating a down circulant matrix from a given number specifying only the size. Down circulant matrices which are generated from a given number are formed by circular shifting of natural numbers and are more suitable for generating regular weave patterns. On the other hand, down circulant matrices generated from a vector are irregular or unordered and hence quite often give irregular weave graphs Some effective ways of generating plain and twest weave patterns from down circulant matrices are also described. Using these methods, we can easily generate weave pattern of desired size in an easier and 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 twest weave patterns. All twest weave patterns can be generated as expected. Also, it has been tested that plain or twill weaves can be combined with twest weave patterns to generate more interesting new weave patterns which have similar weave structures such as satin, herringbone, diamond weaves etc.

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