YumnamBrajarani (YuBraj) Twill: A family of generalized twill weaves

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Abstract:

Proposed here is a new family of twill weaves entitled YuBraj-Twill weaves which encompasses the existing twill weaves as well. YuBraj twill weaves are generated from three parameters ups, downs and shift unlike normal or existing twill weaves which are generated from the first two parameters only, i.e., ups and downs. For a given pair of ups and downs, which are positive integers denoting the number of ups and downs in a warp repeat, we can get only one twill weave. However, by using the shift value as a third parameter in YuBraj-Twill weave, we can generate many different weaves for a given pair of ups and down at different shift values. The shift parameter is used to circularly shift the successive columns or rows by the specified shift value to generate different weave patterns. When the shift value is 1, the generated YuBraj-Twill weave becomes a normal twill weave. When the shift value is any positive integer greater than 1, we get new different weave patterns. In other words, the proposed twill weave can be considered as more generalized twill weave. For a given combination or pair of ups and downs, it can generate significantly many different weaves patterns as compared to the possible number of normal twill weave patterns. It has been established that YuBraj-Twill weaves can generate $16(M\text{-}1)^2$ weave patterns whereas only $2(M\text{-}1)$ weave patterns can be generated in normal twill weaves where M is sum of ups and downs in a weave repeat. So, YuBraj-Twill weaves will enable weavers to produce many new fabric designs to enhance their product quality and demand.

Key Words: Plain weave, Twill weave, Satin, YuBraj-Twill, Z-Twill, S-Twill, Elongated twill, re-arranged Twill.

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I. Introduction

Weaving is the process of making woven fabrics by interlacing vertical threads known as warps with the horizontal threads known as wefts. There are three different types of interlacements used in weaving which are named as plain weaves, twill weaves and Satin weaves [1,2,3,4,9]. Out of these three weaves, twill weave has many derivatives such as diamond weave, herringbone weaves, diaper weaves etc [7]. Usually, these weaves are drawn in a graph paper to know more about the how the warps and wefts are interlaced to generate the pattern. It is cumbersome process and quite often erroneous. So, with the development of information or computer technology, many software applications for used in weave designs [8,10]. In most of these software applications, weave patterns are created by drawing with mouse in the same way weaves are created with pencil on a graph paper. The main advantage of using software application is the spotless editing, modification and correction of the weave designs. Still, they require weavers to have knowledge in drawing using mouse and time consuming. A better solution would be to generate a weave pattern or design by clicking a button. To have such solution a mathematical or algorithmic methods must be formulated to generate weave patterns. In [11,12,13], it has been mentioned that the basic weave patterns used in weaving can be easily generated using circulant matrices. It is found there is striking similarity in the methods how circulant matrices are formed and how weave patterns are formed by circularly shifting the successive interlacement points. Circulant matrices are the basis of many mathematical transforms and operations [5,6]. These matrices can also be used in defining or establishing mathematical relations for generation of various weaves patterns. In this paper, we will be using circulant matrices to develop a more generalized form of twill weavewhich can generate many different weave patterns.

Twill weave is one of the most popular weaves used in weaving of textiles and handicraft items. Twill weave is specified by the number of ups and downs of warps in a repeat size. Traditionally, weavers create twill weaves on a graph paper with pencils with some rules and incorporate these weaves on woven fabrics during weaving process. Such method of creating twill weaves is quite restrictive and hence is not generalizable. So, it is better to represent these weaves in the form of matrices and find how mathematical relation to generate such weave matrices. Weave graphs can be represented well binary matrices with 0's representing black cells and 1's representing white cells.

Suppose X is a twill weave vector of number of warps ups and number of warps down. If warps lines are denoted by black lines and weft lines are denoted by while lines, then the warp ups can be denoted by 0's and warp downs (i.e weft ups) are denoted by 1's. For example, a twill weave vector T of 3 ups and 4 downs can be represented as an array of 3 zeros and 4 ones as T= [1 1 1 1 0 0 0]. Once we have a twill weave vector, we can get a weave matrix by successive circular shifts of the weave vector by 1.

Twill weaves are generated from the twill weave vector by circular shifts of 1. In other words, the shift value is by default 1 and hence is not mentioned in specifying a twill weave. Twill weave are specified only by using the number of warp ups and downs in a repeat size which is the sum of ups and downs. That is, a twill weave of m-ups and n downs represented as Twill(m/n) will have repeat size (m+n), a square matrix of (m+n)x(m+n).
Figure-1(a) Shows a Twill weave matrix of 3 ups and 4 downs whose corresponding weave pattern is shown in Figure-1(b).

$$T(3/4) = \begin{bmatrix} 1&1&1&1&0&0&0 \\ 1&1&1&0&0&0&1 \\ 1&1&0&0&0&1&1 \\ 1&0&0&0&1&1&1 \\ 0&0&0&1&1&1&1 \\ 0&0&1&1&1&1&0 \\ 0&1&1&1&1&0&0 \end{bmatrix}$$

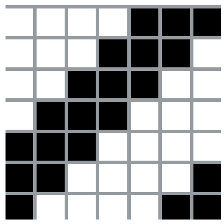


Figure-1(a): Weave Matrix of Twill(3/4) Figure-1(b): Weave pattern of Twill(3/4)

The weave matrix shown in Figure-1 is known as z-twill weave as the zeros or the black cells in the weave graph or pattern follows the diagonal line of the character Z. If we flip the Z- twill we can diagonal black lines follows the diagonal line of character S and hence they are known as S-Twill.

If the circular shifts are performed left-wise, we get a left circulant matrix. If the circular shifts are performed right-wise, we get right circulant matrix. For twill weaves, each row isleft circular shifts of the previous row or each column is the shifting up of the previous column. Shifting columns up will also be considered as left circular shift as mathematically left circular shifting rows and circular shifting of columns up is the same process. Basically, all the basic weaves can be generated conveniently form the circulant matrices. More information on circulant matrices and how the plain weaves, twill weaves and satin weaves are generated can be found in the references [10,11]. It may be noted that right circular shifts of a weave vector do not give a twill weave matrix but a specific kind of broken or rearranged twill weave which we can call Twist weave. More works need to be done on the different forms of Twist weaves and their derivatives.

II. YumnamBrajarani (YuBraj) TwillWeaves

It may be noted that for a given ups and downs we can get only a specific twill weave. We are interested to get more weaves patterns having similar feature of twill weave for any given ups and downs. This can be possible only If we incorporate a third parameter as a shift value. If the shift value is 1, we will get the normal twill weave. If the shift value is other than 1, we can get other weave patterns which may be twill or satin or plain weave like patterns. Weave patterns generated from a weave vector using left circular shifts with specific shift value will be known as YumnamBrajarani Twill (YuBrajTwill in short) as a dedication of the author to his mother (YumnamBrajarani Devi) who was a weaving enthusiast.This twill weave is more generalised than normal twill weave. For a given pair of input parameter of ups and downs, YuBraj-Twill gives more than one weave pattern for different shift values. Figure-2 shows four different YuBraj-Twill weave patterns for 3 ups and 2 downs.

$$\begin{bmatrix} 1&1&0&0&0 \\ 1&0&0&0&1 \\ 0&0&0&1&1 \\ 0&0&1&1&0 \\ 0&1&1&0&0 \end{bmatrix}, \begin{bmatrix} 1&0&0&1&0 \\ 1&0&1&0&0 \\ 0&0&1&0&1 \\ 0&1&0&0&1 \\ 0&1&0&1&0 \end{bmatrix}, \begin{bmatrix} 1&0&1&0&0 \\ 1&0&0&1&0 \\ 0&1&0&1&0 \\ 0&1&0&0&1 \\ 0&0&1&0&1 \end{bmatrix}, \begin{bmatrix} 1&0&0&0&1 \\ 1&1&0&0&0 \\ 0&1&1&0&0 \\ 0&0&1&1&0 \\ 0&0&0&1&1 \end{bmatrix}$$

Figure-2: Different weave matrices YuBrajTwill(3,2) for different shift values

In a twill weave, the numbers of ups and downs of warp or wefts determine the repeat size. The same is true for YuBraj Twill as well. What makes YuBraj Twill to generate more patterns is the shift parameter. So, shift value solely determines how many different weave patterns can be generated for a given repeat size, i.e., ups and downs. To understand more on the role of shift value on YuBraj Twill, let us see how many weave patterns can be obtained for YuBraj Twill of 4 ups and 2 downs. The weave patterns will have repeat size 6 (i.e., 4+2). There are 5 different possible shift values (i.e., 1, 2, 3, 4 and 5) for this repeat size 6. The weave matrices are shown in Figure-3.

$$\begin{bmatrix} 1&1&0&0&0&0\\ 1&0&0&0&0&1\\ 0&0&0&0&1&1\\ 0&0&0&1&1&0\\ 0&0&1&1&0&0\\ 0&1&1&0&0&0 \end{bmatrix}, \begin{bmatrix} 1&0&0&1&0&0\\ 1&0&0&1&0&0\\ 0&0&1&0&0&1\\ 0&0&1&0&0&1\\ 0&1&0&0&1&0\\ 0&1&0&0&1&0 \end{bmatrix}, \begin{bmatrix} 1&0&1&0&1&0\\ 1&0&1&0&1&0\\ 0&0&0&0&0&0\\ 0&1&0&1&0&1\\ 0&1&0&1&0&1\\ 0&0&0&0&0&0 \end{bmatrix}, \begin{bmatrix} 1&0&0&1&0&0\\ 1&0&0&1&0&0\\ 0&1&0&0&1&0\\ 0&1&0&0&1&0\\ 0&0&1&0&0&1\\ 0&0&1&0&0&1 \end{bmatrix}, \begin{bmatrix} 1&0&0&0&0&1\\ 1&1&0&0&0&0\\ 0&1&1&0&0&0\\ 0&0&1&1&0&0\\ 0&0&0&1&1&0\\ 0&0&0&0&1&1 \end{bmatrix}$$

Figure-3: weave matrices for YuBrajTwill(4,2) weaves for shift values 1, 2, 3, 4 and 5.

It may be seen from Figure-3, except the leftmost and the rightmost weave matrices corresponding to shift value 1 and 5, the remaining three matrices have repeated columns. The second weave matrix corresponding to the shift value 2 repeated after 3rd column. The third weave matrix corresponding to shift value 3 repeated after 2nd column. Similarly, we see that the fourth weave matrix repeated after 3rd column. In other words, repeat sizes of the second, third and fourth weave matrices are 6x3, 6x2 and 6x3 respectively as shown in Figure-4.

$$\begin{bmatrix} 1&0&0\\ 1&0&0\\ 0&0&1\\ 0&0&1\\ 0&1&0\\ 0&1&0 \end{bmatrix}, \begin{bmatrix} 1&0\\ 1&0\\ 0&0\\ 0&1\\ 0&1\\ 0&0 \end{bmatrix}, \begin{bmatrix} 1&0&0\\ 1&0&0\\ 0&1&0\\ 0&1&0\\ 0&0&1\\ 0&0&1 \end{bmatrix}$$

Figure-4: Actual weave matrices of YuBraj Twill of 4 ups and 2 downs for shift values 2, 3 and 4.

It may be noticed that that the weave matrix corresponding to shift value 2 in Figure 3 and 4 have rows (3rd and 6th rows counting from top) have all 0's. That is, this weave matrix has float wefts and hence cannot be directly used for weaving. It should be combined with other weave matrix so as to avoid the float wefts. Otherwise, the two float rows must be deleted, which will become a warp rib weave. The weave matrices corresponding to the shift values 1 and 4 (first and the third matrices in Figure-4) are nothing but elongated warp twill weaves. From, Figures 2 and 4, we see that the repeat size of a YuBraj Twill weave is solely dependent on the shift values. Also, we know that we get different types of weaves other than twill weaves.

Let us see what different types of weaves we can get from the YuBraj Twill weave of 5 ups and 1 down for different shift values.

$$\begin{bmatrix} 1&0&0&0&0&0\\ 0&0&0&0&0&1\\ 0&0&0&0&1&0\\ 0&0&0&1&0&0\\ 0&0&1&0&0&0\\ 0&1&0&0&0&0 \end{bmatrix}, \begin{bmatrix} 1&0&0\\ 0&0&0\\ 0&0&1\\ 0&0&0\\ 0&1&0\\ 0&0&0 \end{bmatrix}, \begin{bmatrix} 1&0\\ 0&0\\ 0&0\\ 0&1\\ 0&0\\ 0&0 \end{bmatrix}, \begin{bmatrix} 1&0&0\\ 0&0&0\\ 0&1&0\\ 0&0&0\\ 0&0&1\\ 0&0&0 \end{bmatrix}, \begin{bmatrix} 1&0&0&0&0&0\\ 0&1&0&0&0&0\\ 0&0&1&0&0&0\\ 0&0&0&1&0&0\\ 0&0&0&0&1&0\\ 0&0&0&0&0&1 \end{bmatrix}$$

Figure-5: Weave matrices of YuBraj Twill(5,1) for different shift values 1, 2, 3, 4 and 5.

$$\begin{bmatrix} 1&1&1&0&0&0\\ 1&1&0&0&0&1\\ 1&0&0&0&1&1\\ 0&0&0&1&1&1\\ 0&0&1&1&1&0\\ 0&1&1&1&0&0 \end{bmatrix}, \begin{bmatrix} 1&1&0\\ 1&0&0\\ 1&0&1\\ 0&0&1\\ 0&1&1\\ 0&1&0 \end{bmatrix}, \begin{bmatrix} 1&0\\ 1&0\\ 1&0\\ 0&1\\ 0&1\\ 0&1 \end{bmatrix}, \begin{bmatrix} 1&0&1\\ 1&0&0\\ 1&1&0\\ 0&1&0\\ 0&1&1\\ 0&0&1 \end{bmatrix}, \begin{bmatrix} 1&0&0&0&1&1\\ 1&1&0&0&0&1\\ 1&1&1&0&0&0\\ 0&1&1&1&0&0\\ 0&0&1&1&1&0\\ 0&0&0&1&1&1 \end{bmatrix}$$

Figure-6: Weave matrices of YuBraj Twill (3,3) for different shift values 1, 2, 3, 4 and 5.

From figures 5 and 6, we see that the number of rows of a YuBraj Twill matrix is dependent on the number of ups and downs parameters. That is, the number of rows is the sum of the ups and down. However, the number of columns is dependent mainly on the shift values. Irrespective of ups and downs, the number of columns is 5 for shift values 1 and 5, the number of columns is 3 for shift value 2 and 4 and the number of rows is 2 for shift value 3.

Table-1: Shift values and their effects on repeat sizes of YuBraj Twills

Number of Rows	Possible ups and downs	Shift Values	Number of Columns	Possible repeat sizes
3	(1,2), (2,1)	1, 2	3, 3	3x3, 3x3
4	(1,3), (2,2),(3,1)	1,2,3	4, 2, 4	4x4, 4x2, 4x4
5	(1,4),(2,3),(3,2),(3,1)	1,2,3,4	All 5's	5x5
6	(1,5),(2,4),(3,3),(4,2),(5,1)	1,2,3,4,5	6,3,2,3,6	6x6,6x3, 6x2,6x3,6x6
7	(1,6),(2,5),(3,4),(4,3),(5,2),(1,6)	1, 2, 3, 4, 5, 6	All 7's	7x7
8	(1,7), (2,6), (3,5), (4,4), (5,3), (2,6), (1,7)	1,2,3,4,5,6,7	8,4,8,2,8, 4,8	8x8, 8x4, 8x2, 8x8, 8x4, 8x8
9	(1,8), (2,7), (3,6), (4,5), (5,4), (6,3), (7,2), (8,1)	1, 2, 3, 4, 5, 6, 7, 8	9, 9, 3, 9, 9, 3, 9, 9	9x9, 9x9, 9x3, 9x9, 9x9, 9x3, 9x9, 9x9
10	(1,9), (2,8), (3,7), (4,6), (5,5), (6,4), (7,3), (8,2), (9,1)	1, 2, 3, 4, 5, 6, 7, 8, 9	10, 5, 10, 5, 2, 5, 10, 5, 10	10x10, 10x5, 10x10, 10x5, 10x2, 10x5, 10x10,10x5, 10x10

Table-1 shows the number of columns of YuBraj Twill weaves for different shift values of specific number of rows, the number of ups and downs. From the Table, we see that for a given number of rows (sum of the ups and downs), the number of possible repeat sizes are the same for some and different for many others for different shift values. If we carefully look in the table, it can be seen that the number of rows and the number of columns aresame, if the number of rows is a prime number. For example, for the number of rows 3, 5 and 7 which are all primes, the repeat sizes are only 3x3, 5x5 and 7x7. Also, for shift value 1 and (rows-1), the number of rows and number of columns are the same. If the number of rows is divisible by shift values, then the number of columns is quotient. The numbers columns for shift value 2 for rows 4,6, 8,10 are respectively 2, 3, 4 and 5. The number of columns is also different from the number of rows for shift values which have a common factor with the number of rows, e.g., number of columns for shift number 4 for row numbers 6 and 10 are 3 and 5. From all these observations, we can come to the conclusion that for a given number of rows, the number of columns for any shift number is given by the quotient when the lowest common multiple (LCM) of the number of rows and the shift value is divided by the shift value.

Mathematically, we can derive the relation of the number of rows and columns with shift value in a YuBraj Twill weave as N=LCM(M,K)/K, Where M is the number of rows given by the sum ups and downs of the twill weave, K is the shift value and N is the number of columns.

Number of weave matrices or weave patterns for a given ups and down in a YuBraj Twill weave is equal to the possible shift values which is equal to the number of rows -1 i.e. (ups +downs -1). Also, for a given number of rows, the possible numbers of combinations of ups and downs is rows -1, i.e., (ups and downs -1). Thai is, for 8 rows Twill or YuBraj Twill, there are 7 combinations of ups and downs as (1,7), (2,6), (3,5), (4,4), (5,3), (6,2), and (7,1). For a Twill weave each of these combination gives only one weave matrix or pattern. But for a YuBraj Twill weave, each of these combination gives 7 different weave matrices. So, for a given number of 8 rows, there will be only 7 different weave patterns whereas there will be 49 different weave patterns. In general, there will be $(M-1)^2$different weave patterns for a YuBraj Twill weave type having M rows. We can have 8 different types of YuBraj Twill weaves which will be discussed in the next section when describing about algorithms to generate YuBraj Twill weaves. From, all these descriptions, it can be confirmed that YuBraj Twill can generate significantly much more weave patterns than normal twill weaves.

III. Generation of YuBraj Twill weaves

We know that a YuBraj Twill weave is generated from three different parameters namely, ups, downs and shift values. The repeat size of YuBraj Twill weave is not always the same. The number of rows is fixed by sum of ups and downs whereas the number of columns varies depending on whether the sum of ups and downs has a common factor with the shift value or not. If the sum of ups and downs does not have a common factor with shift value, the size of YuBraj Twill weave will be squaregiven by (ups+downs) rows and (ups + downs) number of columns. If the sum of ups and downs has a common factor, then the number of columns is given by the quotient when the LCM of the sum of ups and downs with shift value is divided by the shift value.

For generation of twill weave, we need to first generate a weave vector of 0's and 1's from desired number of ups and downs in a warp repeat which will be the first row or column of the twill weave, and every successive row or column will be obtained by left or right circular shift by 1. So, the first important task is to generate a weave vector from the ups and downs parameters. There are many ways to generate a weave vector from the ups and downs. One simple way is to generate first M non-negative integers in reverse order and find the integer quotient (i.e., floor value) when divided by the number of ups. The reason why non-negative integers are generated in reverse order is because in weaving graph, the wefts are counted from bottom to top, whereas in vector the elements are counted from top to bottom. So, the algorithm to generate a weave vector from the ups and downs parameters is as follows.

Algorithm to generate weave vector: y=weaveVector(ups, downs)
Input parameters:

```
ups→ Number of warps up in a warp repeat
downs→ Number of warps down in a warp repeat
Outputy: A weave vector of length M (= ups +downs)
Step-1: Compute M=up +downs
Step -2: for i=(M-1) to 0 decrement by -1
Y[i]=1-Floor(i/downs)
        End for
Example: y=weaveVector(4,3)
Step-1 gives M=7
Step 2 gives y=[111 0 000]
```

Once we get a weave vector, then we can generate twill or YuBraj Twill weave by shifting the weave vectors circularly by a specific shift value. Each successive circular shift gives the next column. So, how many successive shifts are to be performed is determined by the number columns of the YuBraj Twill weave for the given ups and downs in a weave repeat. After knowing the repeat size of YuBraj Twill, the next issue is how to perform a right circular shift operation on a weave vector. Performing right circular shift operation can be done by using the modulus operation on sum of the index of shift value with the number of rows or the length of the weave vector. The next issue is mapping the shifted weave vectors as columns. Suppose, Y is a weave vector of length M, we have to generate a weave matrix W of size MxN from w by performing right circular shift operations by shift value K. So, the relation for mapping Y to W for different values rows and columns is as follows.

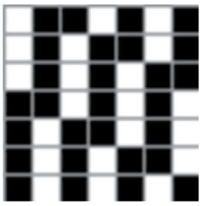
W(i,j)=y[(i+j*K)%M]
Where i=0, 1, 2, … M-1 and j=0,1,2, …, N-1 and K is a positive integer for shift value.
So, following is the algorithm to generate a YuBraj Twill weave.

Algorithm to generate YuBraj Twill: W=YuBraj(ups, downs, K)
Input Parameters:

```
Ups→ number of warps up in a warp repeat
Downs→ number of downs in a warp repeat
K→ shift value
Output Parameters:
W- a weave matrix of size MxN
Step-1: compute M=ups + downs
Step-2: compute N =LCM(M,K)/K
Step-3: Generate weave vector Y from the ups and downs as
        Y=weaveVector(ups,downs)
Step-4: Generate weave matrix W in two for loops as
          For i=0 to M-1
             For j=0 t0 N-1
                 W[I,j]=Y[(i+j*K) %M];
             End for j
        End for i
```

For example, W=YuBraj(4,3,3) gives the following weave matrix whose corresponding weave pattern is also shown aside.

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



Using the above algorithm for YuBraj Twill weave, we can generate many different YuBraj Twill weaves for all possible shift values.

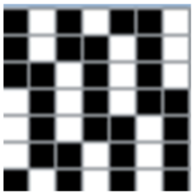
Types of YuBraj Twill weaves:
Different YuBraj Twill weaves patterns can be generated if by changing the way how a weave vector is mapped to a weave matrix. Mapping can be done by flipping the row-wise, column-wise in the output weave or by performing the shifting operation row-wise or column-wise in the weave vector.

YuBrajA Twill:

This is the horizontal flipped or S-Twill version of YuBraj Twill. If H denotes the horizontal flip operation, we can write the relation between YuBraj and YuBrajA Twills as
YuBrajA=H(YuBraj).

The mapping for generation of weave matrix W of YuBrajAtwill from the weave vector Y is as follows.
W[i,N-1-j]=Y[(i+j*K)%M] Where i=0, 1, 2, … M-1 and j=0,1,2, …, N-1 and K is a positive integer for shift value. Example: Weave matrix and weave pattern of YuBrajA(4,3,3)

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



YuBrajB Twill:

This is the vertical flipped version of YuBraj Twill. If V denotes the horizontal flip operation, we can write the relation between YuBraj and YuBrajB Twills as
YuBrajA=V(YuBraj).
The mapping for generation of weave matrix W of YuBrajB twill from the weave vector Y is as follows.
W[M-1-i, j]=y[(i+j*K)%M]
Where i=0, 1, 2, … M-1 and j=0,1,2, …, N-1 and K is a positive integer for shift value.
Example: Weave matrix and weave pattern of YuBrajB(4,3,3)

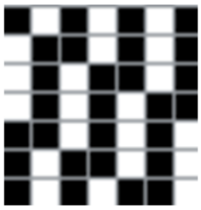
$$\begin{bmatrix} 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 1 & 0 & 1 & 0 \end{bmatrix}$$

YuBrajC Twill:

This is the horizontal and vertical flipped version of YuBraj Twill. If H and V denotes the horizontal flip and vertical flip operations, we can write the relation between YuBraj and YuBrajC Twills as
YuBrajC=H(V(YuBraj)).

The mapping for generation of weave matrix W of YuBrajC twill from the weave vector Y is as follows.
W[M-1-i,N-1-j]=y[(i+j*K)%M]
Where i=0, 1, 2, … M-1 and j=0,1,2, …, N-1 and K is a positive integer for shift value.
Example: Weave matrix and weave pattern of YuBrajC(4,3,3)

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

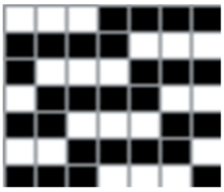


YuBrajD Twill:

This is the transpose version of YuBraj Twill. If (‘) denotes the transpose operation, we can write the relation between YuBraj and YuBrajD Twills as YuBrajA=YuBraj’.

The mapping for generation of weave matrix W of YuBrajD twill from the weave vector Y is as follows.
W[i,j]=y[(i*K+j)%M],
Where i=0, 1, 2, … M-1 and j=0,1,2, …, N-1 and K is a positive integer for shift value.
Example: Weave matrix and weave pattern of YuBrajD(4,3,3)

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



YuBrajE Twill:

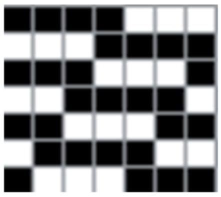
This is the horizontal flipped version of YuBrajD Twill. The relation of the YuBrajE with YuBrajD can be expressed using horizontal flip operation H as follows.
YubrajE=H(YuBrajD)

As YuBrajD is the transpose of YuBraj, we can also expressed YuBrajE as
YubrajE=H(YuBraj’)

The mapping for generation of weave matrix W of YuBrajD twill from the weave vector Y is as follows.
W[i,N-1-j]=Y[(i*K+j)%M]

Where i=0, 1, 2, … M-1 and j=0,1,2, …, N-1 and K is a positive integer for shift value.
Example: Weave matrix and weave pattern of YuBrajE(4,3,3)

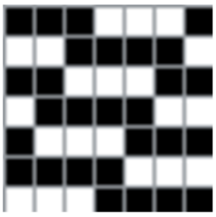
$$\begin{bmatrix} 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 1 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 1 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 1 & 0 & 0 & 0 \end{bmatrix}$$



YuBrajF Twill:

This is the vertical flipped version of YuBrajD Twill. The relation between YuBrajF with YuBrajD and YuBraj Twills can be expressed as
YuBrajF=V(YuBrajD)=V(YuBraj’).
The mapping for generation of weave matrix W of YuBrajF twill from the weave vector Y is as follows.
W[M-1-i,j]=y[(i*K+j)%M]
Where i=0, 1, 2, … M-1 and j=0,1,2, …, N-1 and K is a positive integer for shift value.

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



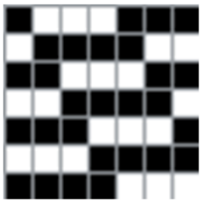
YuBrajG Twill:

This is the horizontal and vertical flipped version of YuBrajD Twill. If H and V respectively denote the horizontal and vertical flip operations, we can express the relation of YubrajG will with YubrajD and YuBraj twill as follows.
YuBrajG=H(V(YuBrajD))
YuBrajG=H(V(Yubraj'))

If we are interested to generate weave matrix of YuBrajG twill directly from the weave vector Y, we can do using the following mapping.
W[M-1-i,N-1-j]=y[(i*K+j)%M]

Where i=0, 1, 2, … M-1 and j=0,1,2, …, N-1 and K is a positive integer for shift value.
Example: Weave matrix and weave pattern of YuBrajG(4,3,3)

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



We have seen that from the same parameter of ups, down and shift values (4,3,3), we can generate 8 different weave patterns from the 8 different variants of YuBraj Twill. By inverting the twills obtained from the YuBraj twill variants, we can get another 8 different twills. So, from the same parameter of ups and down and shift values, we can have 16 different weave patterns.

IV. Experimental Results:

We have seen that YuBraj Twill weaves can be generated many more weave patterns than twill weaves. The reason why this is possible is because of using shift value as an additional parameter in YuBraj Twill weaves along with the ups and downs parameters in normal twill weaves. For a given ups and downs, there are (ups + downs -1) possible number of shift values. For each shift value, we can get a different weave pattern in YuBraj Twill weaves. For a given number of rows M, there are (M-1) possible combination of ups and downs and for each combination of ups and down, (M-1) possible weave patterns can be generated. So, there are $(M-1)^2$ possible weave patterns having M rows in YuBraj Twill weaves. Also, we know that there are 8 different types or variants of YuBraj Twill weaves. Each variant can have an inverse version. In other words, altogether there are $16(M-1)^2$ possible YuBraj Twill weaves having M rows. This is considerably large number of weave patterns for all variants YuBraj Twill weaves for all possible combination of ups and downs making M rows.

In this experimental results section, we will show only two variants of YuBraj Twill weaves, namely YuBraj Twill and YuBraj TwillA for generating weave patterns having only 5 and 7 rows at all possible shift values. There will be 16 different weave patterns of YuBraj Twill weaves having 5 rows corresponding to the four possible combinations of ups and downs as (1,4), (2,3), (3,2) and (4,1). Similarly, there will be 16 different weave patterns having 5 rows in YuBrajA Twill weaves for all possible combination of ups, downs and shift values. To save space, we will consider only 2 ups and 3 downs combinations for both variants of YuBraj Twill weaves. Also, we will consider only 4 ups and 3 downs to generate YuBraj Twill and YuBrajA Twill weave patterns having 7 rows at all possible shift values.

Table-2 shows the YuBraj Twill weave patterns having 2 ups and 3 downs at shift values 1, 2, 3 and 4. The YuBraj Twill weave of 2 ups and 3-downs at shift 1, i.e., the first weave pattern of YuBraj Twill in Table-2 is the z-Twill of 2 ups and 3-downs while the remaining three weaves are some forms of re-arranged twills. On the other hand, the first weave pattern of YuBrajA Twill is the S-twill of 2 ups and 3 downs which is basically the horizontally flipped version of the corresponding Z-twill weave. The other remainingthree weave patterns are re-arranged S-twill weaves. All the weave patterns in Table -2 have 3 white and 2 black cells in every row and columns still they form unique weave patterns. If they are combined appropriately in horizontal or vertical directions, many more nice patterns could be formed.

Table-2: Weave patterns of YuBraj Twill and YuBrajA Twill of 2 ups and 3 downs

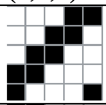
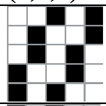
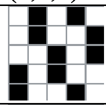
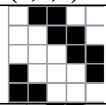
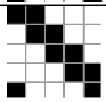
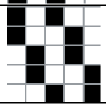
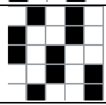
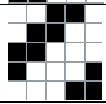
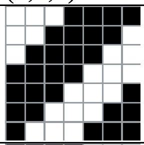
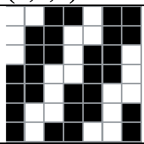
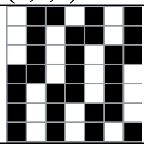
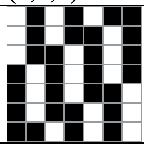
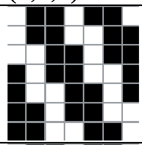
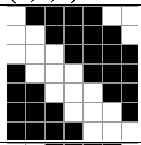
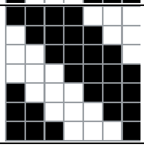
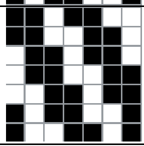
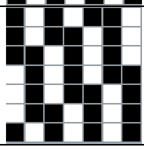
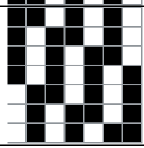
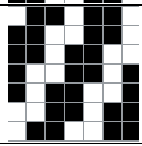
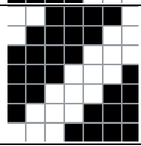
Variants	Parameters – (ups, downs, shift)			
	(2,3,1)	(2,3,2)	(2,3,3)	(2,3,4)
YuBraj Twill				
YuBrajA Twill				

Table-3: Weave patterns of YuBraj Twill and YuBrajA Twill of 4 ups and 3 downs

Variants	Parameters – (ups, downs, shift)					
	(4,3,1)	(4,3,2)	(4,3,3)	(4,3,4)	(4,3,5)	(4,3,6)
YuBraj Twill						
YuBrajA Twill						

Similar is the case for YuBraj Twill weave patterns in Table-3. All weave patterns have the same size 7x7 of 4 ups and 3 downs but they are uniquely different at different shift values. The first weave pattern of YuBraj Twill is the normal Z-twill of 4 ups and 3 downs while the remaining are different shifted or rearranged versions of the Z-twill. Also, the first weave pattern of the YuBrajA twill is the S-twill weave of 4ups and 3-downs. The other remaining weave patterns of the YuBrajA twill are the re-arranged twill weaves of the S-twill. As S-twill and Z-twill weaves are the horizontally flipped versions of one another, we can also get the YuBrajA twill weave patterns from the successive weave patterns of the YuBraj twill weaves by flipping them horizontally. That is, the first weave of YuBrajA Twill is the horizontally flipped version of the first weave of YuBraj Twill weaves. The second weave pattern of the YuBrajA Twill weaves is the horizontally flipped version of the second weave of YuBraj Twill weaves. This way we can get different weave patterns using relation between the different variants of the YuBraj twill weaves. Many nice patterns can also be derived by proper combination of the twill weaves generated from the same or different variants of the YuBraj Twill weaves.

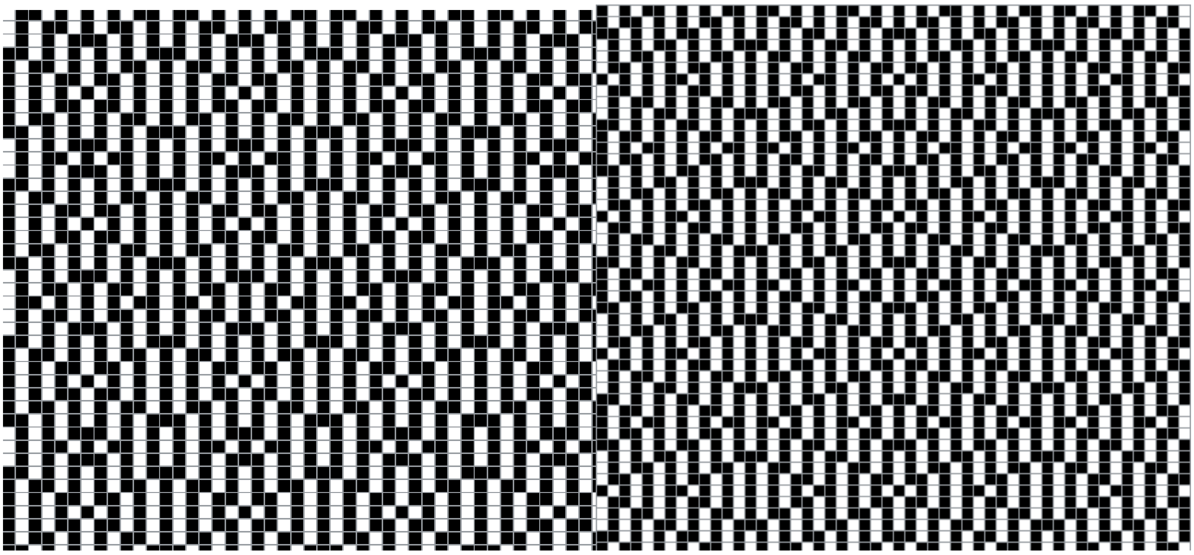
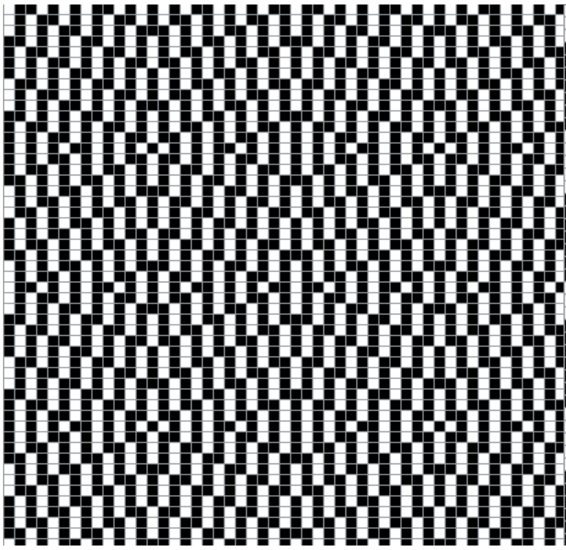


Figure-7(a): Weave pattern from YuBraj Figure-7(b): Weave pattern from YubrajA

Figure-7 shows four larger weave patterns from the combination of YuBraj(4,3,3) and YuBrajA(4,3,3) weave patterns of Table-3.



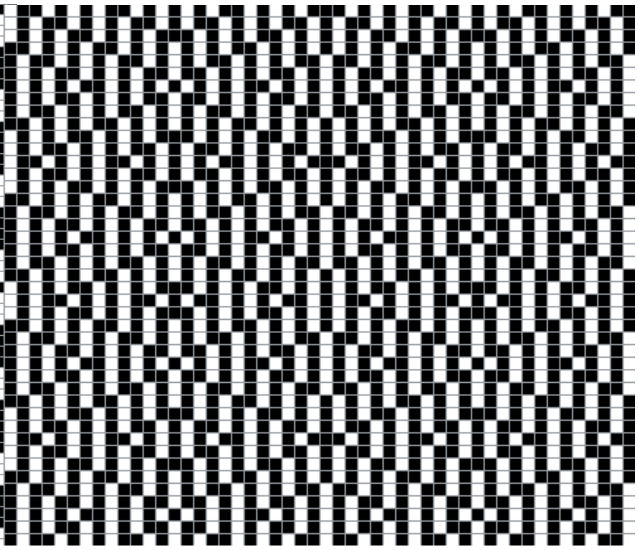


Figure-7(c): Weave pattern from YuBraj   Figure-7(d): Weave Pattern from YuBraj and YuBrajA

The weave pattern of Figure-7(a) and 7(c) are derived from only YuBraj (4, 3,3) twill weave by applying flipping left right operations. The weave pattern in Figure-7(b) is designed from the YuBrajA(4,3,3) only while the weave pattern shown in Figure 7(d) is designed from the combination of YuBraj(4,3,3) and YuBrajA(4,3,3) in vertical and horizontal directions. These weave patterns shows that we can produce many different weave patterns by properly combining one or more weave patterns of YuBraj or its variants.

V. Conclusions:

We have proposed a new and generalized type of twill weave entitled YuBraj Twill weaves which has many more weave patterns as compared with existing twill weaves. These twill weaves are generated from three parameters – ups, downs and shift values unlike normal twill weaves which are generated only from two parameters ups and downs. There are 16 different variants of YuBraj Twill weaves which allows us to generate significantly many different new types of twill weaves.All the methods for generating weave patterns from the different variants have been described. By proper repetition and combination of the new weavesvariants generated from the YuBraj twill, it is expected that weavers will be able to produce attractive woven fabrics with good market demands.

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