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Generation of Shaded Twill and Sateen Weaves

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Abstract
A shaded weave pattern has effect of gradual change in brightness and the darkness in the fabric and hence look smoother. The shading effect can be produced by proper arrangement or combination of two different weave patterns, mainly twill weaves and the sateen weaves and hence they are known as shaded twill weaves and shaded sateen weaves. The shaded twill weaves have shades along the diagonal lines. The shaded sateen weaves have shades along the horizonal or in the vertical directions. Each of these shaded weaves have single and double shaded versions. In most of the weaving literature, the generation of the shaded twill or shaded sateen weaves are done manually by filling the grids of a graph paper or excel sheets on a computer which is time consuming and erroneous. In this paper, we derive the mathematical method along with computer algorithm to enable us generate these shaded patterns in a much easier and efficient way.

Keywords: *Circulant matrix, Shaded weaves, Single Shaded twill, Double shaded twill, Shaded Sateen, Single Shaded Sateen, Double shaded Sateen.*

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I. INTRODUCTION

Shaded weave patterns have gradual change in brightness and look smoother visually. They are generally derived from the two main basic weaves [1,2,3,4], namely twill weaves and Sateen weaves. It may also be derived from other weave structures as well [8]. The way how the shaded twill weaves are derived from the twill weaves is the same way as how multiple twill weave are derived from the twill weaves. The only difference is that in the case of multiple twill weaves, there is no specific relation in the up elements or the down elements. But in the case of shaded twill weaves, there is common difference in the up or down elements. In other words, we can simply say that shaded twill weaves are the multiple twill weaves in which there is a common difference between the up elements or down elements. The common difference between the elements may be negative if the elements are in ascending order or positive if the elements are in descending order. Usually for shaded twill weaves, the up elements are in descending orders and down elements are in descending order.

Shaded twill weaves follow certain mathematical properties. If we carefully observe their properties, it would be clearly seen that the shaded twill weaves are also a kind of the left circulant matrix in the sense that any column or row greater than 1 is obtained by circularly shifting its previous row or column towards left. More about circulant matrices and how plain and twill weaves are generated using left circulant matrices are described in papers [6]. On study, it is found that shaded twill weaves can be generated as the left circulant matrices. The shade structures in the case of twill weaves are aligned diagonally.

We can also have the shade structure spread in horizontal and vertical direction. Such shade structures can be obtained from the sateen weaves and are known as shaded sateen weaves. Usually, shaded sateen weaves are drawn manually by repeating a regular sateen weave and increasing the number of warp ups in each subsequent repeat by 1 until the repeat has only one weft down. The same process can also be applied to the irregular sateen to get shaded sateen weaves. This process can also be represented mathematically and implemented in the form of an algorithm so that shaded sateen weaves can be easily generated in a computer program. For this, we need to generate a sateen weave (regular or irregular) and then follow the repeat filling process to increase the number of warps-ups in subsequent repeat. More about generation of regular and irregular sateen weaves from left circulant matrices can be found in [7]. Generating shaded weaves mathematically or algorithmically has many advantages over manual drawing. The first advantage is that it saves time and efforts. The second one is the flexibility. That is many different types of shaded weaves can be generated easily by simply changing the input parameters. The third advantage is, it is error free. Shaded weaves require more numbers of heald shafts for implementation into fabric. Hence it is difficult to implement in dobby loom and is mainly used in jacquard looms [10,11,12]. To simplify the implementation process instead of direct loom structure, different color schemes are also used which enhances the look and feel of the implemented fabric [9,13].

This paper is divided into four main sections. Section 2 describes about the shaded twill weaves its properties. How the single and the double shaded twill weaves are described and the corresponding algorithms are also provided. Section 3 describes types and properties of shaded sateen weaves. Also, how single shaded and double shaded sateen weaves are generated are described in this section. Conclusions and remarks section is given in Section 4.

II. SHADED TWILL WEAVES

Shaded twill weaves are mainly classified into two types depending on the shading structures introduced in the woven fabric. They are known as single shaded twill weaves and double shaded twill weaves. In a single shaded twill weave, the shades are introduced by gradual variation of shades from dark to light or from light to dark. In a double shaded twill weave, the shades are introduced from dark to light and light to dark.

Single-Shaded Twill Weaves

Single-shaded twill weaves are a specific type of twill design in which the weave exhibits a uniform diagonal texture or pattern throughout the fabric. These weave structures with diagonal ridges have consistent depth and spacing, creating a uniform appearance. As a result, these twill weaves allow for a higher thread count compared to plain weaves, giving the fabric a tighter and stronger construction. In other words, single-shaded twill weaves have tightly packed structure which enhances the fabric's resistance to wear and tear, making it ideal for heavy-duty applications. Twill fabrics are more pliable than plain weaves, providing better drape and comfort. The diagonal structure reduces creasing, ensuring the fabric maintains its shape over time. They are used in a variety of applications, from apparel like denim and chinos to home furnishings like curtains and upholstery.

Generation of Single Shaded Twill Weaves

Single shaded twill weaves are basically multiple twill weaves in which the numerator values are in descending order and the denominator values are in ascending order. The gradual decrease and increase in the numerator and denominator introduce the shade effect in the generated twill weaves. The number of elements in both the numerator and the denominators must be the same. That is, the number of ups and number of downs in the resulted shaded twill weave are the same.

So, if $(m_1, m_2, m_3, \dots, m_k)$and $(n_1, n_2, n_3, \dots, n_k)$are the numerator and denominator of a multiple twill weave, then it becomes a single shaded twill weaves, when the numerator elements are in descending order and the numerator elements are in ascending order. The reverse order, i.e., the numerator elements in ascending order or denominator elements in descending order will also give a shaded structures with different lines along the diagonal. The size of the resulting weave pattern of a single shaded twill is given summing all elements in both the numerators and denominators. That is, for a single shaded twill weave with k elements in both numerator and denominator with respective common differences as d and e, the size of the resulted single-shaded twill weave is given by

(m + (m-d)+(m-2d) + ..+(m-(k-1)d) + (n + (n+e) + (n+2e)+ … + (n+(k-1)e)
=km - (1 + 2 + …+(k-1))d + kn+(1+2+…+ (k-1)e
=k(m+n) +(1+2+ …+(k-1))(e-d)
=k(m+n)+0.5(e-d)(k-1)k

That is, for a single shaded twill weaves of k elements $(m_1, m_2, m_3, \dots, m_k)$/ $(n_1, n_2, n_3, \dots, n_k)$ in which the common difference of the elements in the numerator and denominators are respectively -d and e, the size is given by $=k\{(m_1 + n_1) + 0.5(e - d)(k - 1)\}$

If d==e, then the size becomes $k(m_1 + n_1)$, where m_1 and n_1 are first elements in the numerator and the denominator.

For example, for a multiple twill weave (4,3,2)/(1,3,5), the size is given by sum of all numbers in both numerator and the denominator as 18. The same can be computed using the above formula.

Here, the number of elements k in both numerator and denominator is 3. The first terms are m=4, and n=1. The common differences are d=1 and e=2. So, the size is given by

k{(m+n)+0.5(e-d)(k-1)}=3{(4+1)+0.5(2-1)2}=3(5+1)=3*6=18

For a single shaded twill weave (3,2,1)/(1,2,3) , the size in a single repeat is given by 3(3+1)=12.

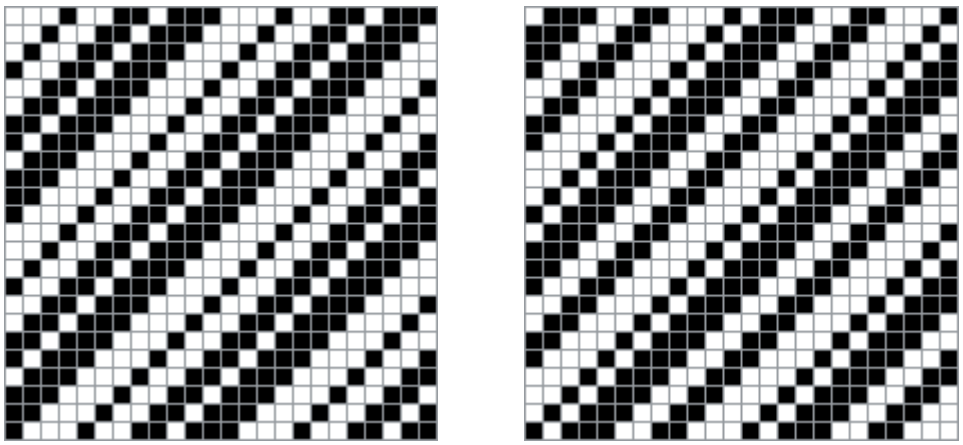
Algorithm to generate Single shaded twill weaves

Steps:

1. Get the input sequences of numerator and denominator of a single shaded twill weave
2. Determine the size from the given input sequences
3. Form a row or column vector of 0's and ones corresponding to the ups and downs of warps

4. Form a left circulant matrix from the corresponding row or column vector to get the desired weave matrix of the single shaded twill weave.

In Figure 1, two single shaded twill weaves generated from (3,2,1)/(1,2,3) and (1,2,3)/(3,2,1) are shown. Each of these single shaded twill weaves are shown in two repeat size for clear visualization.



(a) (b)

Figure-1: Single shaded twill weaves (a) (3,2,1)/(1,2,3) (b) (1,2,3)/(3,2

Double-Shaded Twill Weaves

Double-shaded twill weaves are a type of twill pattern that creates a contrasting or gradated shading effect across the fabric. This variation in shading results from alterations in the interlacing pattern, typically by introducing different weave structures or thread densities in alternating sections. The outcome is a fabric with a dynamic interplay of light and dark tones, providing a layered appearance. Unlike the uniform texture of single-shaded twills, double-shaded twills exhibit variations in their diagonal patterns that create light and dark zones. These weaves often require a more intricate loom setup to alternate patterns effectively, such as combining 2/1 and 3/1 twills in a single fabric. Depending on the shading technique, double-shaded twills may have subtle or pronounced textural differences between the shaded areas.

The dual-tone effect adds sophistication and visual interest, making these fabrics popular in fashion and interior design. The blend of functionality and style enables use in a wider range of applications than single-shaded twills. Retaining the core strength of the twill weave, these fabrics are still highly resilient. The shading effect allows for innovative designs, such as gradients or patterns that mimic shadow effects.

Generation of Double Shaded Twill weaves

Double-shaded twill weaves are a blend of technical sophistication and artistic design. Their ability to incorporate dual tones and textures into a durable fabric makes them ideal for both practical and decorative purposes. From fashion to interior design, double-shaded twills are a versatile choice that showcases the evolution of weaving technology and creativity.

Size of a double shaded twill weave depends on how the shaded pattern is generated. Generally, there are two ways to generate double shaded twill weaves are from a single shaded twill weave. The first one is formed by concatenating the single shaded twill weave with its reflected version about the last element. The second method is by concatenating the single shaded twill weave with its reflected version. The concatenation may be performed either in the horizontal or in the vertical way depending on whether the double shaded twill weave is elongated weft-wise or warp-wise.

Suppose, $(m_1, m_2, m_3, \dots, m_k)/(n_1, n_2, n_3, \dots, n_k)$ is a single shaded twill weave where the numerator elements are in descending order having a common difference d and the denominator elements are in ascending order having a common difference e. Then, a double shaded twill weave can be generated by reflecting around the last elements of both the numerator and denominator as

$$(m_1, m_2, m_3, \dots, m_k, m_{k-1}, m_{k-2}, m_{k-3}, \dots, m_1)/(n_1, n_2, n_3, \dots, n_k, n_{k-1}, n_{k-2}, n_3, \dots, n_1)$$

The size of the double shaded twill is given by

$$2(m_1 + m_2 + m_3 + \dots + m_{k-1}) + m_k + 2(n_1 + n_2 + n_3 + \dots + n_{k-1}) + n_k$$
$$= (k-1)\{2(m_1 + n_1) + (e-d)(k-2)\} + (m_k + n_k)$$

That is, the size of double shaded twill weave corresponding to single shaded twill weave whose numerator has k elements with common difference d and the denominator elements with common difference e is given by

$$(k-1)\{2(m_1 + n_1) + (e-d)(k-2)\} + (m_k + n_k).$$

In case, both the common differences of the numerator and the denominator are the same, (i.e., d==e), the size of the double shaded twill weave becomes $2(k-1)(m_1+n_1)+(m_k+n_k)$.

For example, the size of the double shaded twill weave formed by reflecting about the last element of the single shaded twill weave (3,2,1)/(1,2,3) is 20.

The double shaded twill weave is given by (3,2,1,2,3)/(1,2,3,2,1), its size is given by

$2(k-1)(m_1+n_1)+(m_k+n_k)$, where k=3, $m_1=3$, $n_1=1$ and $m_3=1$, $n_3=3$.

By putting theses value, we compute the size of the corresponding double shaded twill weave as

2(3-1)(3+1)+(1+3)=16+4=20.

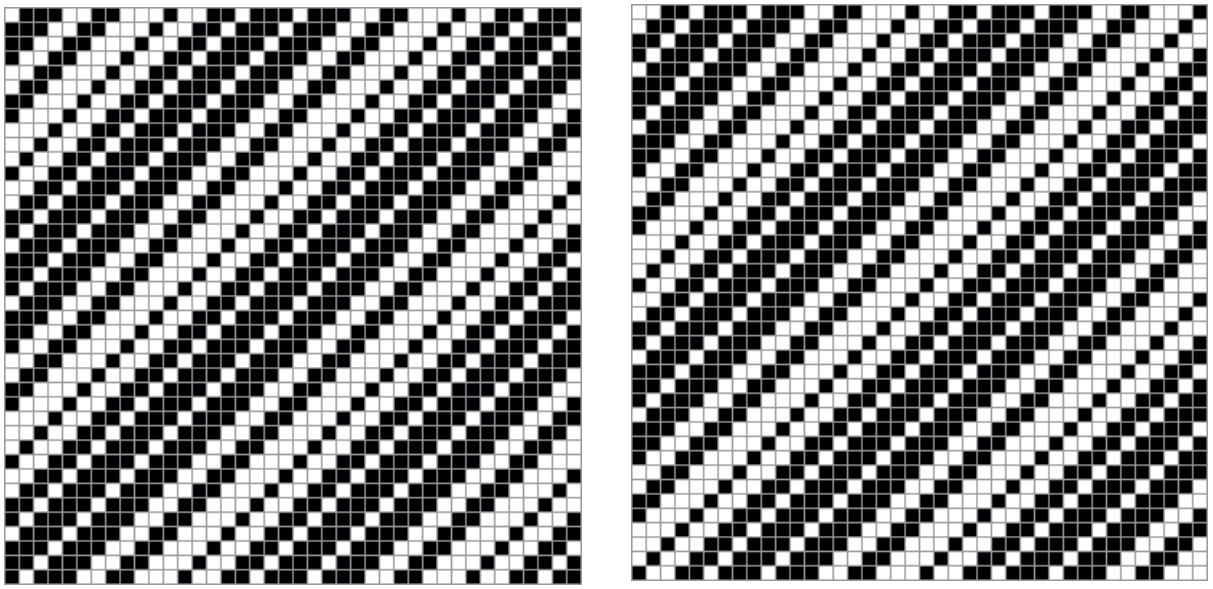
In the similar way, we can easily determine the size of a double shaded twill weave formed by concatenating a single twill weave with its reflected version. In such case, the size is double the size of the single shaded twill weave. However, quite often the last elements of numerator and denominators are removed to make the size equal to the size of the double shaded twill weave generated by the first method.

Algorithm to generate double shaded twill weave

Steps:

1. Get a single shaded twill weave as input
2. Generate the reflected version of single shaded twill weave
3. Delete the first or last column of the reflected single shaded twill weave
4. Concatenate the single shaded twill weave in (1) with the updated reflected version in (3) or in (2) in horizontal or vertical direction.

Figure-2 shows the two different double shaded twill weaves. The first one in Figure-2(a) is generated by the above algorithm in which the first column of the reflected version (in step-3) is deleted. The single size of the generated shaded twill weave is 20, but for clear visualization 2 repeat size is shown.



(a) (b)

Figure-2: Double shaded twill weave (a) (3,2,1,2,3)/(1,2,3,2,1) and (b) (1,2,3,3,2)/(3,2,1,1,2)

III. SHADED SATEEN WEAVES

In shaded weaves, shades are introduced by gradually increasing the number of black pixels successive repeats. As they are formed by combining repeats of specific sateen weaves, the shape of the resulted shaded sateen weave is rectangular in shape either elongated in horizontal or in vertical direction depending on whether the repeats are combined in horizontal or vertical direction. Similar to shaded twill weaves, there are two different shaded sateen weaves – Single shaded Sateen weaves and double shaded sateen weaves as described below.

Single-Shaded Sateen Weaves

Single-shaded sateen weaves are characterized by their uniform surface appearance, with no variation in shade or texture across the fabric. The smooth and even distribution of weft threads dominates the design, creating a seamless and uninterrupted finish. The term "single-shaded" refers to the consistent interplay of light across the fabric, resulting in a unified aesthetic without patterns, gradients, or contrasting textures.

The fabrics generated from single shaded sateen weaves are used for elegant clothing items like blouses, dresses, and linings, offering a touch of sophistication and comfort. Sateen weave fabrics appear in curtains, tablecloths, and cushion covers, lending a refined and polished look to interiors. Fabrics like sateen are also used in quilting and crafting, where their consistent texture provides an ideal base.

While single-shaded twill weaves prioritize strength and a textured diagonal pattern, single-shaded sateen weaves focus on softness, smoothness, and luster. Each has its unique strengths, with sateen being more aligned with luxury and aesthetics.

Generation of Single Shaded Sateen Weaves:

Single-shaded sateen weaves represent the pinnacle of elegance in textiles. Their consistent surface, soft texture, and light-reflective properties make them a popular choice for luxury home textiles and apparel. Despite the challenges in production and care, their timeless appeal ensures they remain a favorite among designers and consumers alike. Whether in a bedroom, wardrobe, or interior décor, single-shaded sateen weaves bring a touch of sophistication and comfort to any setting.

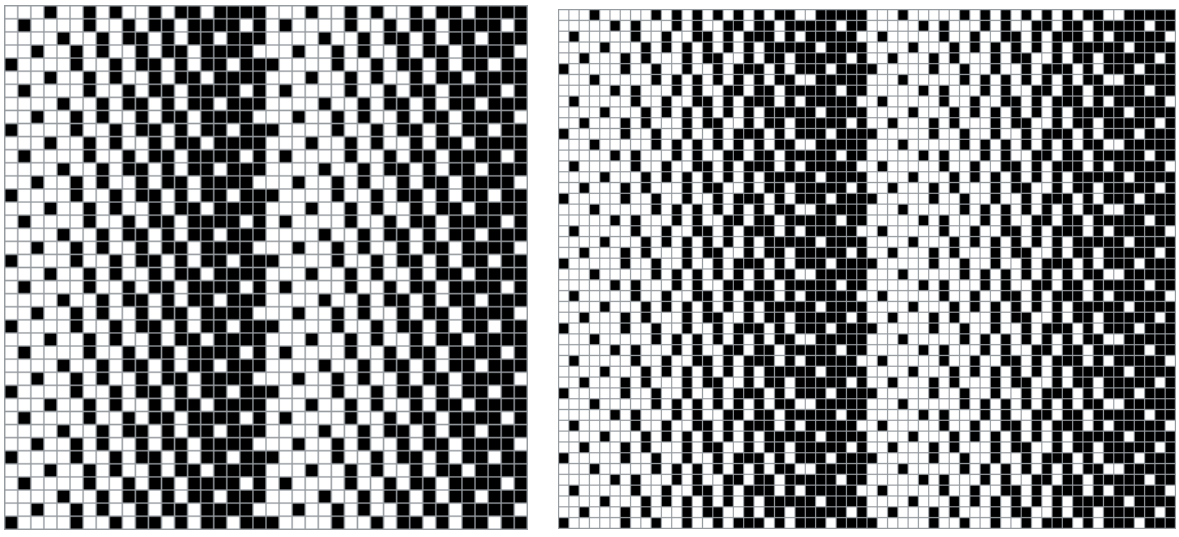
Sateen weaves are renowned for their smooth, lustrous finish, achieved through a unique interlacing pattern that allows the weft threads to dominate the fabric surface. This construction results in a soft, luxurious fabric often used in bedding, apparel, and decorative textiles. A double-shaded sateen weave takes this classic design to the next level by incorporating variations in shading or tonal contrast within the weave, creating a sophisticated interplay of light and shadow.

Algorithm to generate single shaded Sateen weave

Steps:

1. Generate a satin weave of desired size m and move number k
2. Repeat the satin weave horizontally or vertically (m-1) times
3. Fill the rth repeat with extra (r-1) points cyclically above each interlacement point in the repeat.

That is, in the 2nd repeat fill 1 extra interlacement point above existing interlacement point in the 2nd repeat. In the 3rd repeat, fill 2 extra interlacement points above existing interlacement point in the 3rd repeat. The process continues for all the remaining repeats. Figure-3 shows single shaded sateen weaves generated from (5,2) stateen and (6-end) irregular sateen weaves.



(a) (b)

Figure-3: (a) Single shaded satin (5,2), (b) Single Shaded Satin (6-end)

Double-Shaded Sateen Weaves

Double-shaded sateen weaves feature alternating sections or patterns of light and dark tones, either through changes in weave structure, thread type, or color. This dual-tonal effect enhances the visual appeal and depth of the fabric, making it stand out from the uniformity of single-shaded sateen. The contrast can be subtle or pronounced, depending on the design intent and the materials used.

The interplay of light and dark tones adds sophistication and visual interest, elevating the fabric's overall appeal. Retaining the smooth and soft finish of sateen, double-shaded designs combine luxury with artistic flair. The dual-tone effect allows for creative applications in various products, from high-end bedding to elegant clothing. Designers can tailor the level of shading contrast to suit specific design themes or applications. Double-shaded sateen weaves are popular in high-end bedding, such as duvet covers, pillowcases, and sheets, where their refined appearance complements luxury interiors. These weaves are used in formal and semi-formal garments, like blouses, dresses, and ties, offering a blend of comfort and style.

Curtains, cushions, and table linens made from double-shaded sateen bring elegance to living spaces. Double-shaded sateen weaves are also used in decorative quilting and crafting projects where texture and depth are essential

Generation of double shaded Sateen weaves

Double shaded sateen weaves have two continuous shade effects from light to dense and dense to light. The way of generating the double shaded sateen weaves is done in the same way as single shaded satin weaves. A double shaded sateen weave can be generated by combining single shaded sateen weave with its flipped version and removing the first or last repeat.

Suppose, X is a single shaded satin weave derived from a sateen weave of size m and X" is the flipped version of X. Then, the double shaded satin weave Y corresponding to X is given by

Y=[X X"] for horizontal combination

Y=[X; X"] for vertical combination

The size of Y is given by m by 2L or 2L by m depending on whether the double shaded satin weave is formed by horizontal or vertical combination.

Quite often the double shaded satin weav6e fabrics are formed by repeated combination of the double shaded satin weaves. In such cases, if the repetition in the border area is to be avoided, the first and the last satin weave repeats are eliminated in Y. As a result, the size of the double shaded satin weave becomes m by (2(L -m)) or (2(L -m)) by m.

We know L of a single shaded satin weave is given by m(m-1). So, 2(L-m) becomes 2m(m-2) after simplification. In other words, for a given satin weave of size m by m, the size of a double shaded satin weave derived is given by m by 2m(m-2) for horizontal combination or 2m(m-2) by m for vertical combination. From this, we can derive the number of repeats in the double shaded satin weave as 2(m-2).

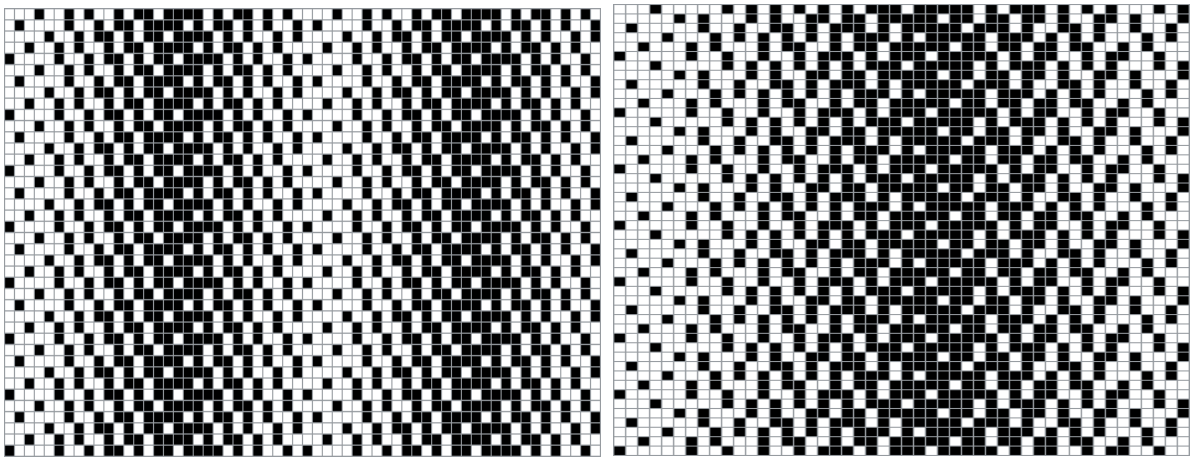
Algorithm to generate double shaded sateen weaves

Steps:

1. Generate a single shaded satin weave of size m
2. Find the number of repeats in the double shaded satin weave
3. Generate blank weave matrix of size determined in (b)
4. Flip single shaded sateen weave generated in (a)
5. Remove the first and the last columns or rows for horizontal or vertical combination
6. Combine (a) and (d) to (c) to generate the double shaded sateen weave

The double shaded sateen weaves can be generated both from the regular as well as from the irregular sateen weaves. The changes in the shade structures are slightly different in case of regular and irregular sateen weaves as these two sateen weaves have different structures. The double weave structures generated from the regular sateen weave weaves are smoother in looks as the change in the shades are continuous. The double shaded sateen weaves generated from the irregular sateen weaves have discontinuous shades as the interlacement points in irregular sateen weaves are not continuous.

Figure-4 shows the double shaded sateen weaves. The weave structure in Figure-4(a) is generated from the regular sateen weave (5,2) and the weave structure in Figure-4(b) is generated from the irregular sateen weave (6-end). Frome these two weave structures, it could be seen the weave structure in Figure-4(a) is smoother than the weave structure in Figure-4(b).



(a) (b)

Figure-4: (a) Double Shaded satin (5,2) and (b) Double Shaded satin(6-end)

While single-shaded sateen fabrics focus on simplicity and uniformity, double-shaded designs offer greater visual complexity and depth. This makes double-shaded sateen weaves more suitable for decorative and statement pieces, while single-shaded versions excel in understated elegance and functionality.

IV. CONCLUSION

In this paper, we describe the different methods of generation shaded twill and shaded sateen weaves. The shaded twill weaves have shaded ridge lines along the diagonal. Both the methods for generation of single shaded and double shaded twill weaves along with the algorithms are given which can be directly implemented as computer program to generate these shaded twill weaves. Also, shaded weave structures which have shaded ridges along the horizontal and vertical lines are described. These weave structures are generated from the sateen weaves. The methods for generating single shaded sateen weaves and double shaded sateen weaves along with the algorithms are described. Using these algorithms, the shaded weave structures can be easily produced in a computer program instead of drawing them manually consuming lots of time and efforts.

With the introduction of new weave patterns such as YuBraj Twill, Twist, Twest, YuBraj Twist and Twest Weaves, different types of new shaded weave patterns can also be generated using these algorithms for generating shaded weaves.

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